UNITED STATES AIR FORCE

SUMMER RESEARCH PROGRAM -- 1998

HIGH SCHOOL APPRENTICESHIP PROGRAM FINAL REPORTS

VOLUME 15B

WRIGHT LABORATORY

RESEARCH & DEVELOPMENT LABORATORIES

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PREFACE

Reports in this volume are numbered consecutively beginning with number 1. Each report is paginated with the report number followed by consecutive page numbers, e.g., 1-1, 1-2, 1-3; 2-1, 2-2, 2-3.

Due to its length, Volume 15 is bound in three parts, 5A, 5B and 5C. Volume 5A contains #1-18. Volume 5B contains reports #19-36, and Volume 5B contains reports #37-59. The Table of Contents for Volume 5 is included in all parts.

This document is one of a set of 15 volumes describing the 1998 AFOSR Summer Research Program. The following volumes comprise the set:

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1	Program Management Report
	Summer Faculty Research Program (SFRP) Reports
2	Armstrong Laboratory
3	Phillips Laboratory
4	Rome Laboratory
5A & 5B	Wright Laboratory
6	Arnold Engineering Development Center, United States Air Force Academy and Air Logistics Centers
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12	Armstrong Laboratory
13	Phillips Laboratory
14	Rome Laboratory
15A, 15B & 15C	Wright Laboratory

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The United States Air Force Summer Research Program (USAF-SRP) is designed to introduce university, college, and technical institute faculty members, graduate students, and high school students to Air Force research. This is accomplished by the faculty members (Summer Faculty Research Program, (SFRP)), graduate students (Graduate Student Research Program (GSRP)), and high school students (High School Apprenticeship Program (HSAP)) being selected on a nationally advertised competitive basis during the summer intersession period to perform research at Air Force Research Laboratory (AFRL) Technical Directorates, Air Force Air Logistics Centers (ALC), and other AF Laboratories. This volume consists of a program overview, program management statistics, and the final technical reports from the HSAP participants at the Wright Laboratory.

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1. INTRODUCTION

The Summer Research Program (SRP), sponsored by the Air Force Office of Scientific Research (AFOSR), offers paid opportunities for university faculty, graduate students, and high school students to conduct research in U.S. Air Force research laboratories nationwide during the summer.

Introduced by AFOSR in 1978, this innovative program is based on the concept of teaming academic researchers with Air Force scientists in the same disciplines using laboratory facilities and equipment not often available at associates' institutions.

The Summer Faculty Research Program (SFRP) is open annually to approximately 150 faculty members with at least two years of teaching and/or research experience in accredited U.S. colleges, universities, or technical institutions. SFRP associates must be either U.S. citizens or permanent residents.

The Graduate Student Research Program (GSRP) is open annually to approximately 100 graduate students holding a bachelor's or a master's degree; GSRP associates must be U.S. citizens enrolled full time at an accredited institution.

The High School Apprentice Program (HSAP) annually selects about 125 high school students located within a twenty mile commuting distance of participating Air Force laboratories.

AFOSR also offers its research associates an opportunity, under the Summer Research Extension Program (SREP), to continue their AFOSR-sponsored research at their home institutions through the award of research grants. In 1994 the maximum amount of each grant was increased from $20,000 to $25,000, and the number of AFOSR-sponsored grants decreased from 75 to 60. A separate annual report is compiled on the SREP.

The numbers of projected summer research participants in each of the three categories and SREP "grants" are usually increased through direct sponsorship by participating laboratories.

AFOSR's SRP has well served its objectives of building critical links between Air Force research laboratories and the academic community, opening avenues of communications and forging new research relationships between Air Force and academic technical experts in areas of national interest, and strengthening the nation's efforts to sustain careers in science and engineering. The success of the SRP can be gauged from its growth from inception (see Table 1) and from the favorable responses the 1997 participants expressed in end-of-tour SRP evaluations (Appendix B).

AFOSR contracts for administration of the SRP by civilian contractors. The contract was first awarded to Research & Development Laboratories (RDL) in September 1990. After completion of the 1990 contract, RDL (in 1993) won the recompetition for the basic year and four 1-year options.

2. PARTICIPATION IN THE SUMMER RESEARCH PROGRAM

The SRP began with faculty associates in 1979; graduate students were added in 1982 and high school students in 1986. The following table shows the number of associates in the program each year.

YEAR	SRP Participation, by Year			TOTAL
	SFRP	GSRP	HSAP	
1979	70			70
1980	87			87
1981	87			87
1982	91	17		108
1983	101	53		154
1984	152	84		236
1985	154	92		246
1986	158	100	42	300
1987	159	101	73	333
1988	153	107	101	361
1989	168	102	103	373
1990	165	121	132	418
1991	170	142	132	444
1992	185	121	159	464
1993	187	117	136	440
1994	192	117	133	442
1995	190	115	137	442
1996	188	109	138	435
1997	148	98	140	427
1998	85	40	88	213

Beginning in 1993, due to budget cuts, some of the laboratories weren't able to afford to fund as many associates as in previous years. Since then, the number of funded positions has remained fairly constant at a slightly lower level.

3. RECRUITING AND SELECTION

The SRP is conducted on a nationally advertised and competitive-selection basis. The advertising for faculty and graduate students consisted primarily of the mailing of 8,000 52-page SRP brochures to chairpersons of departments relevant to AFOSR research and to administrators of grants in accredited universities, colleges, and technical institutions. Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs) were included. Brochures also went to all participating USAF laboratories, the previous year's participants, and numerous individual requesters (over 1000 annually).

RDL placed advertisements in the following publications: *Black Issues in Higher Education, Winds of Change,* and *IEEE Spectrum.* Because no participants list either *Physics Today* or *Chemical & Engineering News* as being their source of learning about the program for the past several years, advertisements in these magazines were dropped, and the funds were used to cover increases in brochure printing costs.

High school applicants can participate only in laboratories located no more than 20 miles from their residence. Tailored brochures on the HSAP were sent to the head counselors of 180 high schools in the vicinity of participating laboratories, with instructions for publicizing the program in their schools. High school students selected to serve at Wright Laboratory's Armament Directorate (Eglin Air Force Base, Florida) serve eleven weeks as opposed to the eight weeks normally worked by high school students at all other participating laboratories.

Each SFRP or GSRP applicant is given a first, second, and third choice of laboratory. High school students who have more than one laboratory or directorate near their homes are also given first, second, and third choices.

Laboratories make their selections and prioritize their nominees. AFOSR then determines the number to be funded at each laboratory and approves laboratories' selections.

Subsequently, laboratories use their own funds to sponsor additional candidates. Some selectees do not accept the appointment, so alternate candidates are chosen. This multi-step selection procedure results in some candidates being notified of their acceptance after scheduled deadlines. The total applicants and participants for 1998 are shown in this table.

1998 Applicants and Participants			
PARTICIPANT CATEGORY	**TOTAL APPLICANTS**	**SELECTEES**	**DECLINING SELECTEES**
SFRP	382	85	13
(HBCU/MI)	(0)	(0)	(0)
GSRP	130	40	7
(HBCU/MI)	(0)	(0)	(0)
HSAP	328	88	22
TOTAL	840	213	42

4. SITE VISITS

During June and July of 1998, representatives of both AFOSR/NI and RDL visited each participating laboratory to provide briefings, answer questions, and resolve problems for both laboratory personnel and participants. The objective was to ensure that the SRP would be as constructive as possible for all participants. Both SRP participants and RDL representatives found these visits beneficial. At many of the laboratories, this was the only opportunity for all participants to meet at one time to share their experiences and exchange ideas.

5. HISTORICALLY BLACK COLLEGES AND UNIVERSITIES AND MINORITY INSTITUTIONS (HBCU/MIs)

Before 1993, an RDL program representative visited from seven to ten different HBCU/MIs annually to promote interest in the SRP among the faculty and graduate students. These efforts were marginally effective, yielding a doubling of HBCI/MI applicants. In an effort to achieve AFOSR's goal of 10% of all applicants and selectees being HBCU/MI qualified, the RDL team decided to try other avenues of approach to increase the number of qualified applicants. Through the combined efforts of the AFOSR Program Office at Bolling AFB and RDL, two very active minority groups were found, HACU (Hispanic American Colleges and Universities) and AISES (American Indian Science and Engineering Society). RDL is in communication with representatives of each of these organizations on a monthly basis to keep up with the their activities and special events. Both organizations have widely-distributed magazines/quarterlies in which RDL placed ads.

Since 1994 the number of both SFRP and GSRP HBCU/MI applicants and participants has increased ten-fold, from about two dozen SFRP applicants and a half dozen selectees to over 100 applicants and two dozen selectees, and a half-dozen GSRP applicants and two or three selectees to 18 applicants and 7 or 8 selectees. Since 1993, the SFRP had a two-fold applicant increase and a two-fold selectee increase. Since 1993, the GSRP had a three-fold applicant increase and a three to four-fold increase in selectees.

In addition to RDL's special recruiting efforts, AFOSR attempts each year to obtain additional funding or use leftover funding from cancellations the past year to fund HBCU/MI associates.

SRP HBCU/MI Participation, By Year				
YEAR	**SFRP**		**GSRP**	
	Applicants	**Participants**	**Applicants**	**Participants**
1985	76	23	15	11
1986	70	18	20	10
1987	82	32	32	10
1988	53	17	23	14
1989	39	15	13	4
1990	43	14	17	3
1991	42	13	8	5
1992	70	13	9	5
1993	60	13	6	2
1994	90	16	11	6
1995	90	21	20	8
1996	119	27	18	7

6. SRP FUNDING SOURCES

Funding sources for the 1998 SRP were the AFOSR-provided slots for the basic contract and laboratory funds. Funding sources by category for the 1998 SRP selected participants are shown here.

1998 SRP FUNDING CATEGORY	SFRP	GSRP	HSAP
AFOSR Basic Allocation Funds	67	38	75
USAF Laboratory Funds	17	2	13
Slots Added by AFOSR (Leftover Funds)	0	0	0
HBCU/MI By AFOSR (Using Procured Addn'l Funds)	0	0	N/A
TOTAL	84	40	88

7. COMPENSATION FOR PARTICIPANTS

Compensation for SRP participants, per five-day work week, is shown in this table.

1998 SRP Associate Compensation

PARTICIPANT CATEGORY	1991	1992	1993	1994	1995	1996	1997	1998
Faculty Members	$690	$718	$740	$740	$740	$770	$770	$793
Graduate Student (Master's Degree)	$425	$442	$455	$455	$455	$470	$470	$484
Graduate Student (Bachelor's Degree)	$365	$380	$391	$391	$391	$400	$400	$412
High School Student (First Year)	$200	$200	$200	$200	$200	$200	$200	$200
High School Student (Subsequent Years)	$240	$240	$240	$240	$240	$240	$240	$240

The program also offered associates whose homes were more than 50 miles from the laboratory an expense allowance (seven days per week) of $52/day for faculty and $41/day for graduate students. Transportation to the laboratory at the beginning of their tour and back to their home destinations at the end was also reimbursed for these participants. Of the combined SFRP and GSRP associates, 65 % claimed travel reimbursements at an average round-trip cost of $730.

Faculty members were encouraged to visit their laboratories before their summer tour began. All costs of these orientation visits were reimbursed. Forty-three percent (85 out of 188) of faculty associates took orientation trips at an average cost of $449. By contrast, in 1993, 58 % of SFRP associates elected to take an orientation visits at an average cost of $685; that was the highest percentage of

associates opting to take an orientation trip since RDL has administered the SRP, and the highest average cost of an orientation trip.

Program participants submitted biweekly vouchers countersigned by their laboratory research focal point, and RDL issued paychecks so as to arrive in associates' hands two weeks later.

This is the third year of using direct deposit for the SFRP and GSRP associates. The process went much more smoothly with respect to obtaining required information from the associates, about 15% of the associates' information needed clarification in order for direct deposit to properly function as opposed to 7% from last year. The remaining associates received their stipend and expense payments via checks sent in the US mail.

HSAP program participants were considered actual RDL employees, and their respective state and federal income tax and Social Security were withheld from their paychecks. By the nature of their independent research, SFRP and GSRP program participants were considered to be consultants or independent contractors. As such, SFRP and GSRP associates were responsible for their own income taxes, Social Security, and insurance.

8. CONTENTS OF THE 1998 REPORT

The complete set of reports for the 1998 SRP includes this program management report (Volume 1) augmented by fifteen volumes of final research reports by the 1998 associates, as indicated below:

1998 SRP Final Report Volume Assignments

LABORATORY	SFRP	GSRP	HSAP
Armstrong	2	7	12
Phillips	3	8	13
Rome	4	9	14
Wright	5A, 5B	10	15
AEDC, ALCs, USAFA, WHMC	6	11	

APPENDIX A – PROGRAM STATISTICAL SUMMARY

A. Colleges/Universities Represented

Selected SFRP associates represented 169 different colleges, universities, and institutions, GSRP associates represented 95 different colleges, universities, and institutions.

B. States Represented

SFRP -Applicants came from 47 states plus Washington D.C. Selectees represent 44 states.

GSRP - Applicants came from 44 states. Selectees represent 32 states.

HSAP - Applicants came from thirteen states. Selectees represent nine states.

Total Number of Participants	
SFRP	85
GSRP	40
HSAP	88
TOTAL	213

Degrees Represented			
	SFRP	GSRP	TOTAL
Doctoral	83	0	83
Master's	1	3	4
Bachelor's	0	22	22
TOTAL	186	25	109

SFRP Academic Titles	
Assistant Professor	36
Associate Professor	34
Professor	15
Instructor	0
Chairman	0
Visiting Professor	0
Visiting Assoc. Prof.	0
Research Associate	0
TOTAL	85

Source of Learning About the SRP		
Category	Applicants	Selectees
Applied/participated in prior years	177	47
Colleague familiar with SRP	104	24
Brochure mailed to institution	101	21
Contact with Air Force laboratory	101	39
IEEE Spectrum	12	1
BIIHE	4	0
Other source	117	30
TOTAL	616	162

APPENDIX B – SRP EVALUATION RESPONSES

1. OVERVIEW

Evaluations were completed and returned to RDL by four groups at the completion of the SRP. The number of respondents in each group is shown below.

Table B-1. Total SRP Evaluations Received

Evaluation Group	Responses
SFRP & GSRPs	100
HSAPs	75
USAF Laboratory Focal Points	84
USAF Laboratory HSAP Mentors	6

All groups indicate unanimous enthusiasm for the SRP experience.

The summarized recommendations for program improvement from both associates and laboratory personnel are listed below:

A. Better preparation on the labs' part prior to associates' arrival (i.e., office space, computer assets, clearly defined scope of work).

B. Faculty Associates suggest higher stipends for SFRP associates.

C. Both HSAP Air Force laboratory mentors and associates would like the summer tour extended from the current 8 weeks to either 10 or 11 weeks; the groups state it takes 4-6 weeks just to get high school students up-to-speed on what's going on at laboratory. (Note: this same argument was used to raise the faculty and graduate student participation time a few years ago.)

2. 1998 USAF LABORATORY FOCAL POINT (LFP) EVALUATION RESPONSES

The summarized results listed below are from the 84 LFP evaluations received.

1. LFP evaluations received and associate preferences:

Table B-2. Air Force LFP Evaluation Responses (By Type)

		How Many Associates Would You Prefer To Get ?								(% Response)			
		SFRP				GSRP (w/Univ Professor)				GSRP (w/o Univ Professor)			
Lab	**Evals Recv'd**	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**
AEDC	0	-	-	-	-	-	-	-	-	-	-	-	-
WHMC	0	-	-	-	-	-	-	-	-	-	-	-	-
AL	7	28	28	28	14	54	14	28	0	86	0	14	0
USAFA	1	0	100	0	0	100	0	0	0	0	100	0	0
PL	25	40	40	16	4	88	12	0	0	84	12	4	0
RL	5	60	40	0	0	80	10	0	0	100	0	0	0
WL	46	30	43	20	6	78	17	4	0	93	4	2	0
Total	**84**	**32%**	**50%**	**13%**	**5%**	**80%**	**11%**	**6%**	**0%**	**73%**	**23%**	**4%**	**0%**

LFP Evaluation Summary. The summarized responses, by laboratory, are listed on the following page. LFPs were asked to rate the following questions on a scale from 1 (below average) to 5 (above average).

2. LFPs involved in SRP associate application evaluation process:
   a. Time available for evaluation of applications:
   b. Adequacy of applications for selection process:
3. Value of orientation trips:
4. Length of research tour:
5. a. Benefits of associate's work to laboratory:
   b. Benefits of associate's work to Air Force:
6. a. Enhancement of research qualifications for LFP and staff:
   b. Enhancement of research qualifications for SFRP associate:
   c. Enhancement of research qualifications for GSRP associate:
7. a. Enhancement of knowledge for LFP and staff:
   b. Enhancement of knowledge for SFRP associate:
   c. Enhancement of knowledge for GSRP associate:
8. Value of Air Force and university links:
9. Potential for future collaboration:
10. a. Your working relationship with SFRP:
    b. Your working relationship with GSRP:
11. Expenditure of your time worthwhile:

(Continued on next page)

12. Quality of program literature for associate:
13. a. Quality of RDL's communications with you:
    b. Quality of RDL's communications with associates:
14. Overall assessment of SRP:

Table B-3. Laboratory Focal Point Reponses to above questions

	AEDC	*AL*	*USAFA*	*PL*	*RL*	*WHMC*	*WL*
# Evals Recv'd	0	7	1	14	5	0	46
Question #							
2	-	86 %	0 %	88 %	80 %	-	85 %
2a	-	4.3	n/a	3.8	4.0	-	3.6
2b	-	4.0	n/a	3.9	4.5	-	4.1
3	-	4.5	n/a	4.3	4.3	-	3.7
4	-	4.1	4.0	4.1	4.2	-	3.9
5a	-	4.3	5.0	4.3	4.6	-	4.4
5b	-	4.5	n/a	4.2	4.6	-	4.3
6a	-	4.5	5.0	4.0	4.4	-	4.3
6b	-	4.3	n/a	4.1	5.0	-	4.4
6c	-	3.7	5.0	3.5	5.0	-	4.3
7a	-	4.7	5.0	4.0	4.4	-	4.3
7b	-	4.3	n/a	4.2	5.0	-	4.4
7c	-	4.0	5.0	3.9	5.0	-	4.3
8	-	4.6	4.0	4.5	4.6	-	4.3
9	-	4.9	5.0	4.4	4.8	-	4.2
10a	-	5.0	n/a	4.6	4.6	-	4.6
10b	-	4.7	5.0	3.9	5.0	-	4.4
11	-	4.6	5.0	4.4	4.8	-	4.4
12	-	4.0	4.0	4.0	4.2	-	3.8
13a	-	3.2	4.0	3.5	3.8	-	3.4
13b	-	3.4	4.0	3.6	4.5	-	3.6
14	-	4.4	5.0	4.4	4.8	-	4.4

3. 1998 SFRP & GSRP EVALUATION RESPONSES

The summarized results listed below are from the 120 SFRP/GSRP evaluations received.

Associates were asked to rate the following questions on a scale from 1 (below average) to 5 (above average) - by Air Force base results and over-all results of the 1998 evaluations are listed after the questions.

1. The match between the laboratories research and your field:
2. Your working relationship with your LFP:
3. Enhancement of your academic qualifications:
4. Enhancement of your research qualifications:
5. Lab readiness for you: LFP, task, plan:
6. Lab readiness for you: equipment, supplies, facilities:
7. Lab resources:
8. Lab research and administrative support:
9. Adequacy of brochure and associate handbook:
10. RDL communications with you:
11. Overall payment procedures:
12. Overall assessment of the SRP:
13. a. Would you apply again?
    b. Will you continue this or related research?
14. Was length of your tour satisfactory?
15. Percentage of associates who experienced difficulties in finding housing:
16. Where did you stay during your SRP tour?
    a. At Home:
    b. With Friend:
    c. On Local Economy:
    d. Base Quarters:
17. Value of orientation visit:
    a. Essential:
    b. Convenient:
    c. Not Worth Cost:
    d. Not Used:

SFRP and GSRP associate's responses are listed in tabular format on the following page.

Table B-4. 1997 SFRP & GSRP Associate Responses to SRP Evaluation

# res	Arnold 6	Brooks 48	Edwards 6	Eglin 14	Griffis 31	Hanscom 19	Kelly 3	Kirtland 32	Lackland 1	Robins 2	Tyndall 10	WPAFB 85	average 257
1	4.8	4.4	4.6	4.7	4.4	4.9	4.6	4.6	5.0	5.0	4.0	4.7	4.6
2	5.0	4.6	4.1	4.9	4.7	4.7	5.0	4.7	5.0	5.0	4.6	4.8	4.7
3	4.5	4.4	4.0	4.6	4.3	4.2	4.3	4.4	5.0	5.0	4.5	4.3	4.4
4	4.3	4.5	3.8	4.6	4.4	4.4	4.3	4.6	5.0	4.0	4.4	4.5	4.5
5	4.5	4.3	3.3	4.8	4.4	4.5	4.3	4.2	5.0	5.0	3.9	4.4	4.4
6	4.3	4.3	3.7	4.7	4.4	4.5	4.0	3.8	5.0	5.0	3.8	4.2	4.2
7	4.5	4.4	4.2	4.8	4.5	4.3	4.3	4.1	5.0	5.0	4.3	4.3	4.4
8	4.5	4.6	3.0	4.9	4.4	4.3	4.3	4.5	5.0	5.0	4.7	4.5	4.5
9	4.7	4.5	4.7	4.5	4.3	4.5	4.7	4.3	5.0	5.0	4.1	4.5	4.5
10	4.2	4.4	4.7	4.4	4.1	4.1	4.0	4.2	5.0	4.5	3.6	4.4	4.3
11	3.8	4.1	4.5	4.0	3.9	4.1	4.0	4.0	3.0	4.0	3.7	4.0	4.0
12	5.7	4.7	4.3	4.9	4.5	4.9	4.7	4.6	5.0	4.5	4.6	4.5	4.6
Numbers below are percentages													
13a	83	90	83	93	87	75	100	81	100	100	100	86	87
13b	100	89	83	100	94	98	100	94	100	100	100	94	93
14	83	96	100	90	87	80	100	92	100	100	70	84	88
15	17	6	0	33	20	76	33	25	0	100	20	8	39
16a	-	26	17	9	38	23	33	4	-	-	-	30	
16b	100	33	-	40	-	8	-	-	-	-	36	2	
16c	-	41	83	40	62	69	67	96	100	100	64	68	
16d	-	-	-	-	-	-	-	-	-	-	-	0	
17a	-	33	100	17	50	14	67	39	-	50	40	31	35
17b	-	21	-	17	10	14	-	24	-	50	20	16	16
17c	-	-	-	-	10	7	-	-	-	-	-	2	3
17d	100	46	-	66	30	69	33	37	100	-	40	51	46

4. 1998 USAF LABORATORY HSAP MENTOR EVALUATION RESPONSES

Not enough evaluations received (5 total) from Mentors to do useful summary.

5. 1998 HSAP EVALUATION RESPONSES

The summarized results listed below are from the 23 HSAP evaluations received.

HSAP apprentices were asked to rate the following questions on a scale from 1 (below average) to 5 (above average)

1. Your influence on selection of topic/type of work.
2. Working relationship with mentor, other lab scientists.
3. Enhancement of your academic qualifications.
4. Technically challenging work.
5. Lab readiness for you: mentor, task, work plan, equipment.
6. Influence on your career.
7. Increased interest in math/science.
8. Lab research & administrative support.
9. Adequacy of RDL's Apprentice Handbook and administrative materials.
10. Responsiveness of RDL communications.
11. Overall payment procedures.
12. Overall assessment of SRP value to you.
13. Would you apply again next year? Yes (92 %)
14. Will you pursue future studies related to this research? Yes (68 %)
15. Was Tour length satisfactory? Yes (82 %)

	Arnold	Brooks	Edwards	Eglin	Griffiss	Hanscom	Kirtland	Tyndall	WPAFB	Totals
# resp	5	19	7	15	13	2	7	5	40	113
1	2.8	3.3	3.4	3.5	3.4	4.0	3.2	3.6	3.6	3.4
2	4.4	4.6	4.5	4.8	4.6	4.0	4.4	4.0	4.6	4.6
3	4.0	4.2	4.1	4.3	4.5	5.0	4.3	4.6	4.4	4.4
4	3.6	3.9	4.0	4.5	4.2	5.0	4.6	3.8	4.3	4.2
5	4.4	4.1	3.7	4.5	4.1	3.0	3.9	3.6	3.9	4.0
6	3.2	3.6	3.6	4.1	3.8	5.0	3.3	3.8	3.6	3.7
7	2.8	4.1	4.0	3.9	3.9	5.0	3.6	4.0	4.0	3.9
8	3.8	4.1	4.0	4.3	4.0	4.0	4.3	3.8	4.3	4.2
9	4.4	3.6	4.1	4.1	3.5	4.0	3.9	4.0	3.7	3.8
10	4.0	3.8	4.1	3.7	4.1	4.0	3.9	2.4	3.8	3.8
11	4.2	4.2	3.7	3.9	3.8	3.0	3.7	2.6	3.7	3.8
12	4.0	4.5	4.9	4.6	4.6	5.0	4.6	4.2	4.3	4.5
Numbers below are percentages										
13	60%	95%	100%	100%	85%	100%	100%	100%	90%	92%
14	20%	80%	71%	80%	54%	100%	71%	80%	65%	68%
15	100%	70%	71%	100%	100%	50%	86%	60%	80%	82%

JAVASCRIPT APPLIED TO INTRANET DOCUMENTS

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Final Report for:
High School Apprenticeship Program
AFRL/Wright Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

And

Wright Laboratory

August 1998

JavaScript Applied to Intranet Documents

William B. Haynal
Spring Valley Academy

Abstract

This summer research program involved creating JavaScript-enhanced intranet documents for the Policies and Procedures section of the expanding ML intranet site. That included studying books based on JavaScript and writing small sample programs to gain a working knowledge for syntax and a feel for style. After a working knowledge of JavaScript had been attained, work commenced on the production of JavaScript-enhanced intranet documents via embedding the JavaScript source code directly into the Hypertext Markup Language (HTML) documents.

JavaScript Applied to
Intranet Documents

William B. Haynal

Introduction

To further increase productivity and intra-directorate communication, the Materials Directorate of the Air Force Research Labs is implementing an internal research intranet web-site. This site is posted on an internal web server—however, there are some sections and features that are as of yet incomplete. Among those sections was Policies and Procedures. In order to complete this section, electronic copies had to be converted to web documents. Hypertext Markup Language (HTML) was capable of fulfilling this need, but in order completely implement all of the desired features additional technological tools were needed. The tool that was found to best meet these additional needs was JavaScript. When combined with HTML, JavaScript can greatly enhance the user's experience by making things easier. With it, you can create hints in a web browser's status bar, or validate information that the user has entered into a form before it is sent in for processing by a CGI program. This, and more, is what made JavaScript the likely candidate for the companion to HTML in the Policies and Procedures section of the ML intranet.

Background on JavaScript

JavaScript was created by Netscape Communications Corporation and later endorsed by Sun Microsystems, Incorporated. JavaScript is a scripting language, meaning that each line of code is executed in order, line by line. Its advantages over HTML are, among

others, its ability to have programming loops, variables, and functions. All of those things are impossible to implement in straight HTML, yet quite simple to do in JavaScript. Also, JavaScript embedded in a web page can handle information from other web pages, other windows, and it can communicate with the web browser's windows.

Methodology

The method of creating JavaScript-enhanced pages is by embedding JavaScript within an HTML document. This is accomplished by using the opening `<script>` tag and the closing `</script>` tag. Those tags can appear anywhere in an HTML document. Within those tags is where the JavaScript commands and functions are placed. One of the commands that is useful in the ML intranet is the `window.status` command. Setting it equal to a string will cause that string to be displayed in the browser window's status bar. This is useful in giving more detailed information or hints about where a certain link will take you if you click there. This is illustrated in the Figure 1.

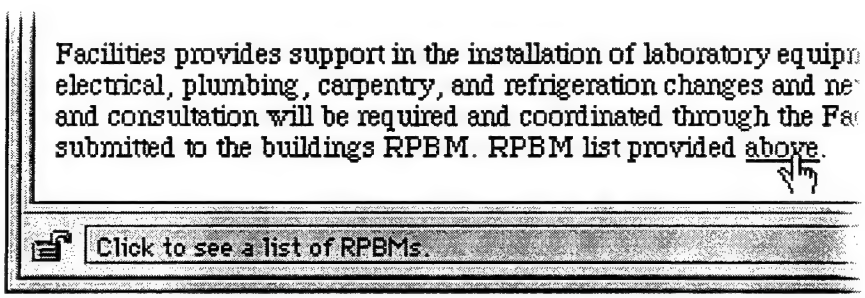

Figure 1 – Typical example of JavaScript's `window.status` command.

Another command that is also quite useful is `document.write()` method. Placing a string inside the parentheses will cause that string to appear in the body of the page, just like it would if it were done with HTML. But unlike HTML, which would be the same text every time, the text displayed can vary depending on, for example, a variable with the inclusion of an if statement. It could even include the variable's value or HTML tags for formatting.

'If' statements are written in the form `if(`*`condition`*` ) {`*`JavaScript commands`*` }` were *condition* is an expression that evaluates to a boolean value and *JavaScript commands* are any number of lines of JavaScript. The commands are executed only if the condition evaluates to true.

Event-handlers are another important aspect of JavaScript. An event handler handles events generated by the user, such as the moving of the mouse or clicking on a link. They are most commonly found in an HTML tag as an attribute. Different HTML tags support different event-handlers, and some HTML tags do not support any event-handlers. One of the most frequently used event-handler is `mouseOver`, which is written as `onMouseOver="`*`JavaScript Commands`*`"` when it is inside of an HTML tag. *`JavaScript Commands`* is any number of JavaScript commands each separated by a semicolon, or it can be a call to a function that has already been defined in the header of the page.

Placing as much of the JavaScript code in the header of the HTML document as is considered to be good form. In doing so, the rest of the document looks cleaner and is more readable.

All these commands and placements combined together to complete the Policies and Procedures section of the ML intranet. Hints were created in the browser's status bar

and a function checked the input into form before it was submitted to a CGI program that preformed a search.

Results

The use of JavaScript has greatly improved the experience of a user visiting the ML intranet. They can navigate more easily and with more certainty. The pages also have a more customized feel to them, whereas a plain HTML page feels more static. Having a JavaScript function validate form input before it is sent off to a CGI program reduces the load on the server, as well as reduces the amount of time that it takes to detect an error in the inputted data.

Conclusion

In conclusion, the ML intranet site is being greatly improved through the use of new technologies such as JavaScript. Without this new technology the new ML intranet would be less enticing to its visitors, making them less likely to actually use this great information source, thus rendering the entire effort of building the intranet worthless.

OPTIMIZING FORMULATION OF AFFF-EMB USING MIXTURE DESIGNS AND RSPONSE SURFACE METHODS

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Final Report for:
High School Apprenticeship Program
AFRL/Wright Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

And

Wright Laboratory

August 1998

OUTLINE

1) Introduction
2) Defining the Issue
3) Background
    a) AFFF
    b) Mixture
4) Design-Expert
    a) Mixture Model
    b) Mixture Experiment
5) Response Surfaces
    a) Surface Tension
    b) Drain Time
    c) Film Spread
6) Results

OPTIMIZING FORMULATION OF AFFF-EMB USING MIXTURE DESIGNS AND RESPONSE SURFACE METHODS

Jessica L. Hill
Port St. Joe High School

Abstract

Mixture designs and response surface methods can be used to formulate the aqueous film formulation environmentally more benign (AFFF-EMB). A quadratic model was used with four components: water, the organic solvent, hydrocarbon-surfactants, and fluorocarbon-surfactants. The design points were chosen by a software program called Design Expert by Stat Ease, Inc. The program indicated that there was a need of ten mixtures to support a quadratic model plus five replicates and five goodness-of-fit mixtures for a total of twenty.

Each mixture was subjected to six experiments: surface tension, interfacial tension, foam expansion ratio, and a quarter drain time. The results of these experiments lead into the four response surfaces. With the response surfaces optimization can begin and the "sweet spot" can be found. The "sweet spot" is a mixture that will contain what is needed for the correct results. This would be the shorter process of the technique that will be used to compose an AFFF-EMB.

OPTIMIZING FORMULATION OF AFFF-EMB USING MIXTURE DESIGNS AND RESPONSE SURFACE METHODS

Jessica L. Hill
Port St. Joe High School

Introduction

In optimizing the aqueous film formation formula (AFFF) mixture design and response methods were used by the program Design Expert which was written by Stat-Ease. Design Expert is what organizes the responses and forms a mixture model. Design Expert uses mixture design to give the number of mixtures that need to be tested, and responses to give the results needed for the response surfaces. The responses used were surface tension, interfacial tension, draintime, and expansion ratio.

Defining the Issue

AFFF is an excellent fire-fighting agent on hydrocarbon fuel fires, but environmentalists were concerned about it since it contained the ingredients Butyl Carbitol® and fluorocarbon surfactants. The Environmental Protection Agency (EPA) had to regulate Butyl Carbitol because it was on their list of products that can cause air pollution. The EPA decided that if more than a pound was used it should be reported. Then, while the EPA is considering the problem, they have allowed large amounts of BC to be discharged.

The next problem is that the agent contains fluorocarbons that are non-biodegradable. The fluorocarbons would create a problem if they entered into a Wastewater Treatment Plant (WTP). If the fluorocarbons (FC) entered into a WTP they would clean it of all of its bacteria or in other words FCs would "foam" the plant. Now experiments are being done

to try to find a FC that is not as harmful to WTPs. Reducing the environmental impact of AFFF would be very beneficial to the Air Force. Even though AFFF is considered mature technology, the documentation of the attempts to improve of film-forming foam is large and goes back to, the 1970's.

Background

AFFF Background

The Naval Research Laboratory improved their protein foam by producing the aqueous film-forming foam (AFFF). AFFF is composed of fluorocarbon surfactants, hydrocarbon surfactants, and organic solvents. Without these chemicals AFFF would not be an active fire-fighting agent. The fluorocarbon surfactant (FCS) forms a film over the fuel that stops fuel vaporization and extinguishes the fire. Hydrocarbon surfactants (HCS) generate water-containing foam that floats on the fuel. While organic solvents (OS) support the foam by keeping the bubbles from popping as quick. AFFF is different because of its film formation qualities and its very fluid foam, which is important to the quickness of the foam spread.

Mixture Background

Statistical research on mixture experiments is relatively a new activity. Most of the theory and methodology have appeared in the last thirty years. One of the original and still current writers is Cornell; in 1990 he wrote an article in Journal Quality Technology (JQT). Some other reports that have been written recently (1989) include the writers: Donev, Koons, and Mikaeili. The most useful material on mixtures has been current except for, in 1958 H. Scheffe's pioneering article, in 1955 Claringbold's book which is in regard to administering joint dosage of hormones to mice, and. pioneering article in 1953 Quenouille's book about the discussion of mixtures.

Design-Expert

Design-Expert is a menu driven program that has two major parts: mixture design or mixture experiment analysis. Design and analysis is used when the factors are independent from one another. A strong point of Design-Expert is its graphic capabilities in the mixture module. Plotting points and forming tables are also made easier through this software. The designs that are available in the mixture designs are simplex lattice, simplex cetroid, D-optimal, and distance-based. Each is available in a linear model, a quadratic model, and cubic models.

Mixture Model

A model is the mathematical expression that is fit to the data. Design-Expert uses polynomial models. Polynomials are mathematical equations that are used to estimate a relationship between terms. Polynomials are used in two forms: generalized for the mixture models and in specific form for response surfaces. When judging how good a model is do not just look at how well it fits the data, but how well the model predicts other points. The model may fit, but it will say nothing about how good the model will predict the data points that are not in the design.

Mixture Experiment

A mixture experiment is an experiment that uses the proportions of ingredients to arrive at an optimum. The model used in this experiment was a quadratic. Since a quadratic was used mixture design gave the number of experiments that needed to be done. The number of experiments was ten for testing, five as replicates and five more for just goodness of fit. The mixture experiment or the responses used were surface tension, interfacial tension spreading coefficient, the foam expansion ratio, and the quarter drain time. Other planned experiments are film spread, lifetime, burnback, and extinguishment times. Each of these responses is done on the twenty mixtures, and each variable forms a response surface. Each response has an optimum, and we obtain the percentage of each ingredient for that optimum mixture. The optimums of the five response surfaces form a "sweet spot," which is a mixture that will contain what is needed for the best AFFF.

Results

At this time half of the response surfaces have been done. The spreading coefficient was found to fit the quadratic model. In optimizing the spreading coefficient the target of the coefficient had to be 3 with an importance of 5. The reason for this was because MIL-F-24385 calls for no less than 3 for the spreading coefficient. After optimizing the response the mixture that was given contained 68.6% H2O, 15.5% OS, 11.5% HCS, 4.4% FCS. The attachments that are included with this report will show the results of the tension test, drain test, expansion ratio, and spreading coefficient. The attachments will also show the design summary, the response surfaces, and optimization of the spreading coefficient.

Response Surface

Surface Tension

The Kuss K10st tensiometer is what was used in measuring the surface tension of the samples. The ring and plate were the two devices used in measuring the surface tension of the samples. The plate method is also known as the Wilhelmy method after its inventor Ludwig F. Wilhelmy (in 1863). The plate is a platinum device and is suspended vertically to the solution. The measuring of the sample depends on the rough surface of the plate. This causes the sample to leap on the plate when the bottom edge of the device is brought in contact with the liquid. After the sample jumps onto the plate it pulls the device down into the liquid when the plate is pulled back up to the surface the Wilhelmy force can be measured.

The other device used in measuring surface tension is the ring. Lecompte Du Nouy made the description of a "ring-tensiometer" in 1919. The measuring tool is a platinum-iridium ring, which is suspended horizontally to the sample. To measure the sample the ring is dipped into the liquid and slowly pulled out of the liquid. The surface of the liquid should still be connected in the ring. The maximum force on the ring is what determines the measurement of the surface tension.

Interfacial Tension

The ring is also used in interfacial tension tests, which has to be done in order to find the spreading coefficient. In the interfacial test there are two phases the heavy phase which is the agent and the lite phase which is the cyclohexane. In the interfacial tests the ring is measuring the tension between the agent and the cyclohexane. These experiments are explained in further attachments.

Spreading Coefficient

The spreading coefficient measures how well the foam will spread across the fuel. The spreading coefficient is obtained by taking the surface tension of the agent and subtracting it from cyclohexane then taking the interfacial tension and subtracting it from the previous answer.

Expansion Ratio and Drain Time

The expansion ratio and drain time test is a quick and easy process that obtains the expansion ration and drain time in the same experiment. The drain time and expansion ratio is achieved by using a blender, scale, stopwatch, graduated cylinder, and a computer to calculate results, plot the curve, and get the equation. The drain time is achieved by timing how long it takes for the foam to drain, putting results in the computer, and using the equation to get the quarter drain time. The expansion ration is received by dividing the foam volume by the weight of the foam. In AFFF the expansion ratio is eight to one. These experiments are further explained in the attachments.

1. Cornell John A., Experiments With Mixtures, John Wiley and Sons, Inc., 1990.
2. C.P. Hanauska, J.L. Scheffey, R.J. Roby, and D.T. Gottuk, "Inproved Formulations of Firefighting Agents for Hydrocarbon Fuel Fires", Hughes Associates, Inc., 1993.
3. Kraber Shari, "Handbook for Experimenter's", Stat-Ease incorporated, 1997.
4. Wendell F. Smith, Mixture Experiments: An Experimental Design Approach To Formulation, The American Chemical Society, 1996.

Surface Tension Test

1. <u>Using the Plate:</u> The plate method is also known as the Wilhelmy method after its inventor Ludwig F. Wilhelmy in 1863. The plate is a platinum device and is suspended vertically to the solution. The measuring of the sample depends on the rough surface of the plate. This causes the sample to leap on the plate when the bottom edge of the device is brought in contact with the liquid. After the sample jumps onto the plate it pulls the device down into the liquid when the plate is pulled back up to the surface the Wilhelmy force can be measured.
    a) Test Setup
        i) Turn on the machine.
        ii) Change the Run-Zero switch to zero, the Ring-Plate switch to plate, and the Temperature-Surface Tension switch to mN/m
        iii) Set vessel speed to 3 or 4
        iv) Set stop adjustment to zero
    b) Clean the Plate
        i) Rinse the plate with distilled water.
        ii) Dry the plate over a Bunsen burner.
        iii) Hold plate in flame for 5 or 10 seconds. Do not let the plate become white hot.
        iv) Carefully place the plate back on the hook and let it cool
    c) Zeroing the Instrument:
        i) Turn the control knob until it is on or close to zero
        ii) Turn the zero adjustment knob until the arrow is over zero. Now the test is ready to begin.
    d) Conducting the Test:
        i) Place the sample on the platform under the plate and raise the platform until the plate is close to the sample
        ii) Switch your Run-Zero switch to run
        iii) Press the vessel up control down until the lower edge of the plate is wet by the sample; when the plate is wet and the tensionmeter automatically takes over release the vessel up control.
        iv) Watch the digital display and record the highest number. After the digits have been recorded the Run-Zero switch should be changed back to zero.
2. <u>Using the Ring:</u> The description of a "ring-tensiometer" was made by Lecompte Du Nouy in 1919. This measuring tool is a platinum-iridium ring, which is suspended horizontally to the sample. To measure the sample the ring is dipped into the liquid and slowly pulled out of the liquid. The geometric measurements for the standard Kruss ring are the wetting length U = 119.95 mm, the mean radius R = 9.545 mm, and the radius of the cross-section of the wire r = 0.185.
    a) <u>Test Setup:</u> The setup is the same as the Plate's setup except the Ring/Plate switch is moved to ring.
    b) <u>Cleaning the Ring:</u> The ring is cleaned the same way the plate is cleaned.
    c) <u>Zeroing the Instrument:</u>

i) If the surface tension is roughly known the digital display is set 10 digits lower than the number expected.

ii) If the surface tension is unknown the digital display is set at zero.

d) Conducting the Test:

i) Shift the Run-Zero switch from zero to run.

ii) Place the sample on the platform and raise the platform until the ring is into the sample

iii) Slowly turn the sample elevation knob so the platform eases down and the ring comes to the surface

iv) When the tensionmeter automatically takes over release the knob and stand back so the results will be accurately recorded.

v) After recording the results shift the Run/Zero switch back to zero

3. Interfacial Tension: It is used in determining the interfacial tension between two different liquids.

a) Test Setup:

i) The Ring/Plate switch is moved to ring

ii) The Vessel Speed is set at one

iii) The stop adjustment is set three to the right of zero

b) Cleaning the Ring: The ring is cleaned the same way as before

c) Zeroing the Instrument:

i) Dip ring into light phase

ii) Zero the instrument the same as before

iii) Take ring out of light phase and place the light phase to the side.

iv) Clean the ring

d) Conducting the Test:

i) Place the sample of the ½ heavy phase on the platform under the ring.

ii) Dip the ring in the heavy phase

iii) Carefully pour the light phase in the heavy phase

iv) Flip the Run-Zero switch to Run

v) Slowly lower the platform until the zero adjustment arrow moves in the negative side and it starts operating automatically. (since the speed is on one it operates very slowly and quietly)

Laboratory Foam Expansion and Drain Time Test

1. Foam Expansion: This procedure is used to create foam and to determine the expansion ratio. With a 3% AFFF solution, this procedure will produce an 8:1 expansion ratio. Foam.

   a) Test Setup:

      i) Tare cylinder being used in measuring foam.

      ii) Prepare AFFF premix and pour 100 ml into a blender.

   b) Conduct Test:

      i) Blend premix on low speed for 12 seconds. Start stop watch when blender starts.

      ii) Pour produced foam into a 200 ml graduated cylinder.

      iii) Scrape off top and quickly clean off any overflowing foam. After this record the weight of the foam.

      iv) Record the foam expansion by dividing foam volume by foam weight.

2. Drain Time: This test is to calculate the ½ and ¼ drain times.

   a) Test Setup: This follows after the foam expansion.

   b) Conduct Test:

      i) Record the time required for draining, for example, 5, 10, 15, and 20 ml of liquid.

      ii) Record 3 or 4 drain times and volumes in a spreadsheet.

      iii) Make a scatter point graph with trendline and formula. Make sure your R squared = just a little lower than .999.

      iv) Take the foam weight and divide it by 2 and 4 to produce the ½ or 50% drain volume and 25% or ¼ drain volume

      v) Take the results of the calculation of iv) and plug them each into the Y = formula.

      vi) Record both the numbers for the ½ and ¼ drain times.

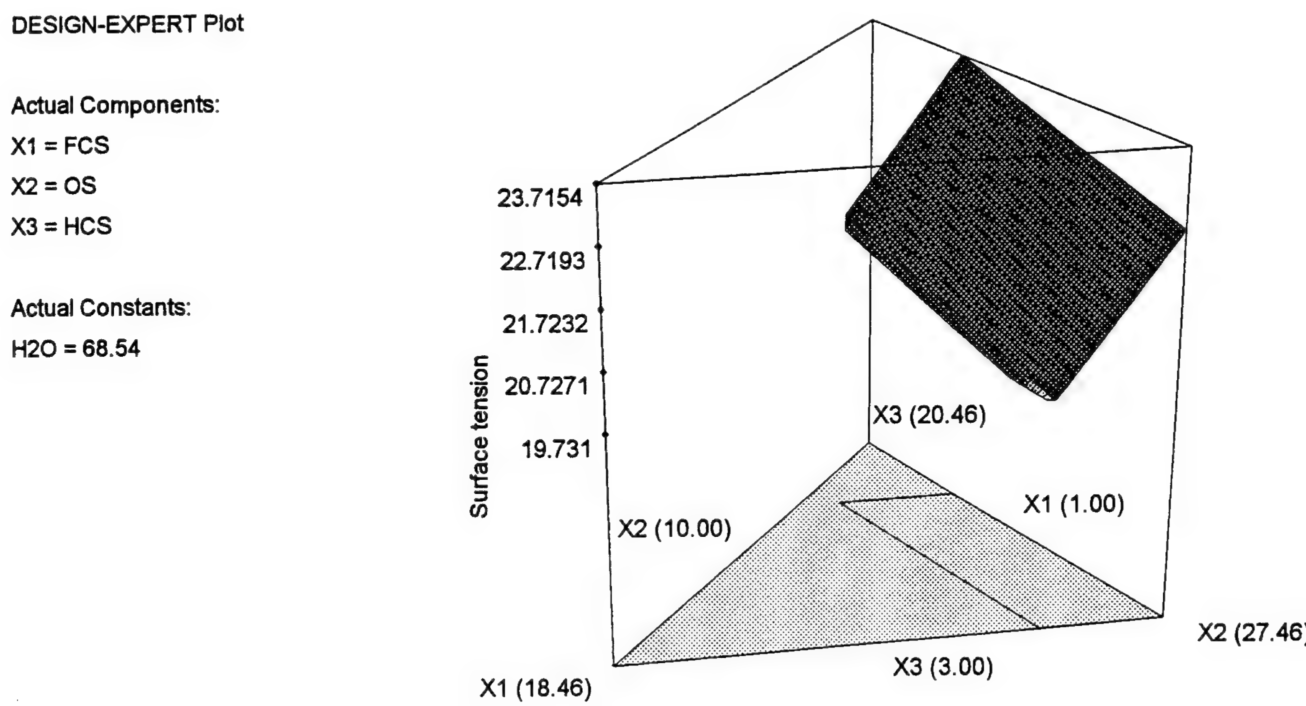
Std	Run	Type	Factor A:H2O	Factor B:OS	Factor C:HCS	Factor D:FCS	Response Surface tension dyne/cm	Response Interfacial tension dyne/cm	Response Spread Coefficient dyne/cm	Response Expansion ratio	Response Drain time sec
1	1	Vertex	60.00	34.00	3.00	3.00	19.8	2.5	2.4	2.4	96.8
2	14	Vertex	75.00	10.00	14.00	1.00	25.4	2.1	-2.8	6	152.2
3	17	Vertex	60.00	24.00	15.00	1.00	25.1	2.1	-2.5	5.5	162.2
4	8	Vertex	75.00	21.00	3.00	1.00	23.5	1.9	-0.7	2.8	250.3
5	13	CentEdge	75.00	13.50	6.50	5.00	20.6	2.1	2	2.9	121.7
6	15	CentEdge	60.00	26.00	9.00	5.00	20.3	2	2.4	3.4	148.8
7	5	CentEdge	67.50	24.50	3.00	5.00	19.5	3.1	2.1	2.3	97
8	3	Vertex	62.00	34.00	3.00	1.00	21.2	1.7	1.8	2.5	103.1
9	12	Center	67.17	21.33	8.67	2.83	21.7	1.8	1.2	3.3	135.9
10	18	Vertex	70.00	10.00	15.00	5.00	20.5	1.9	2.3	4.2	123.7
11	6	CentEdge	67.00	17.00	15.00	1.00	21.2	2	1.5	5.2	150.8
12	2	AxialCB	64.58	27.67	5.83	1.92	19.8	1.7	3.2	2.8	135.4
13	10	AxialCB	71.08	15.67	11.33	1.92	22.5	1.9	0.3	3.6	152.9
14	16	Vertex	60.00	20.00	15.00	5.00	20.4	2	2.3	4.2	170.1
15	19	AxialCB	71.08	19.17	5.83	3.92	20.8	1.9	2	3	124.5
16	7	Vertex	60.00	34.00	3.00	3.00	19.9	1.7	3.1	2.4	103.6
17	9	Vertex	75.00	21.00	3.00	1.00	24.2	2	-1.5	2.6	88.7
18	11	CentEdge	67.50	24.50	3.00	5.00	21	2.6	1.1	2.3	93.7
19	4	CentEdge	75.00	13.50	6.50	5.00	18.8	2.1	3.8	2.9	122.4
20	20	CentEdge	60.00	26.00	9.00	5.00	20.1	1.9	2.7	3.2	145.8

Design Summary

Study Type	Mixture		**Experiments**	20			
Initial Design	D-optimal		**Blocks**	No Blocks			
Design Model	Quadratic						

Response	**Name**	**Units**	**Obs**	**Minimum**	**Maximum**	**Trans**	**Model**
Y1	Surface tensio	dyne/cm	20	18.80	25.40	None	Linear
Y2	Interfacial tensi	dyne/cm	20	1.70	3.10	None	Quadratic
Y3	Spread Coeffic	dyne/cm	20	-2.80	3.80	None	Quadratic
Y4	Expansion rati		20	2.30	6.00	None	Quadratic
Y5	Drain time	sec	20	88.70	250.30	None	Linear

Component	**Name**	**Units**	**Type**	**Low Actual**	**High Actual**	**Low Coded**	**High Coded**
A	H2O		Mixture	60.00	75.00	0.000	0.577
B	OS		Mixture	10.00	34.00	0.000	0.923
C	HCS		Mixture	3.00	15.00	0.000	0.462
D	FCS		Mixture	1.00	5.00	0.000	0.154
				Total =	100.00		



DESIGN-EXPERT Plot
Actual Components:
X1 = FCS
X2 = OS
X3 = HCS
Actual Constants:
H2O = 68.54
Surface tension
23.7154
22.7193
21.7232
20.7271
19.731
X3 (20.46)
X1 (1.00)
X2 (10.00)
X2 (27.46)
X3 (3.00)
X1 (18.46)

DESIGN-EXPERT Plot

Actual Components:

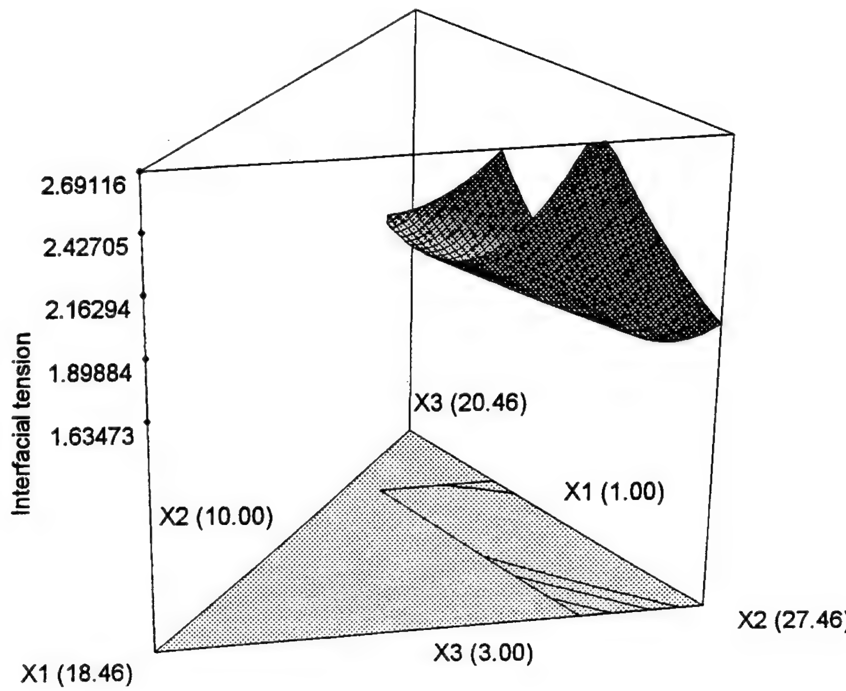
X1 = FCS

X2 = OS

X3 = HCS

Actual Constants:

H2O = 68.54



DESIGN-EXPERT Plot

Actual Components:

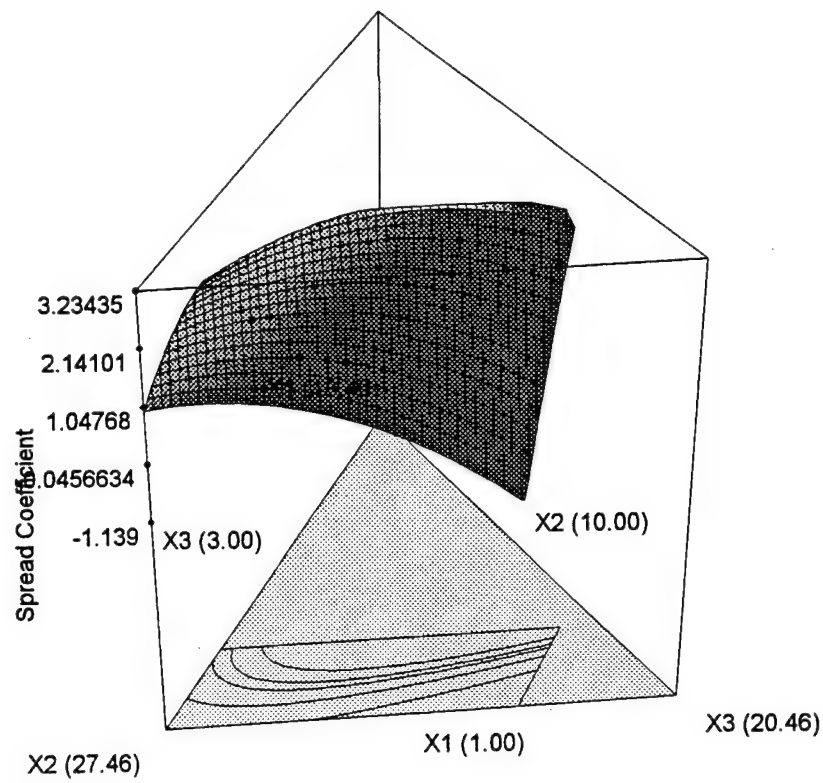
X1 = FCS

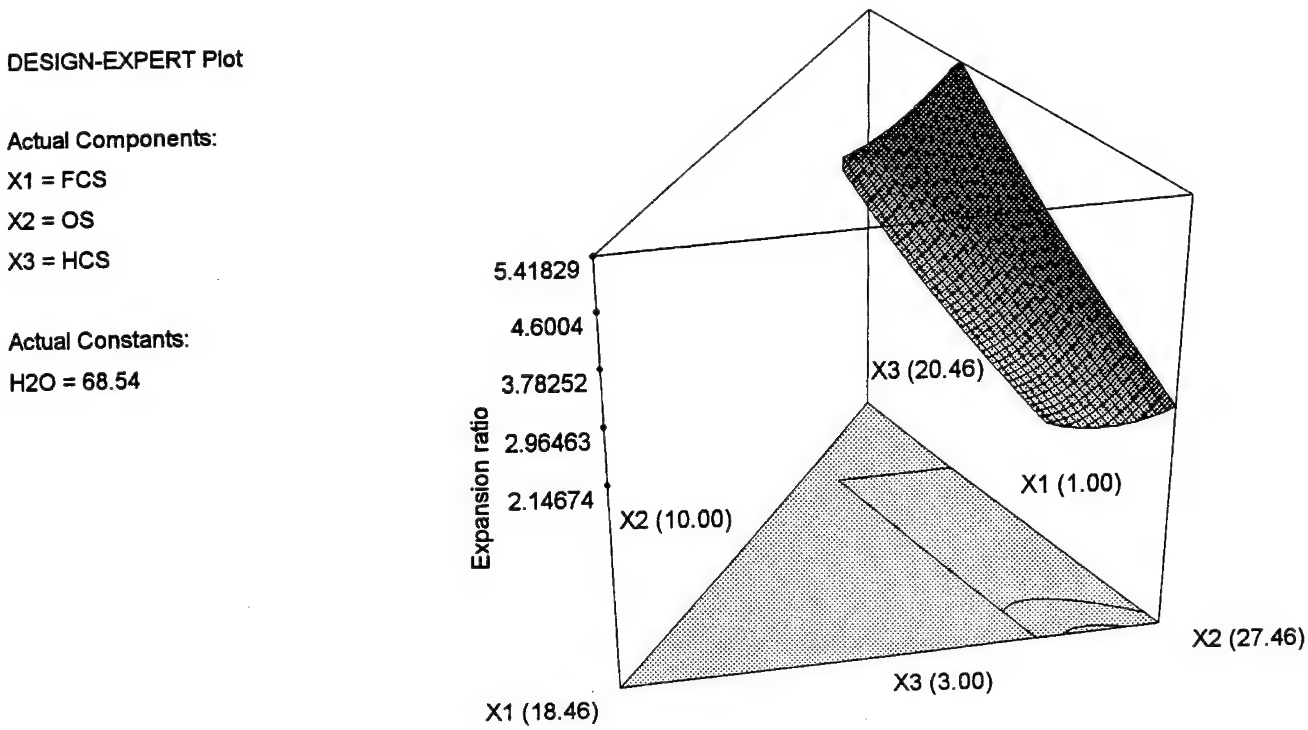
X2 = OS

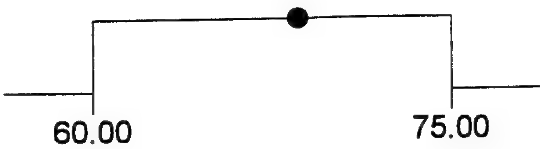
X3 = HCS

Actual Constants:

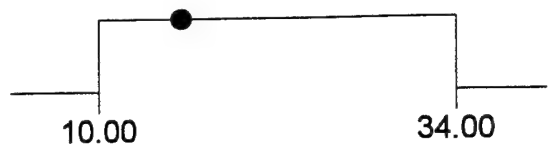
H_2O = 68.54



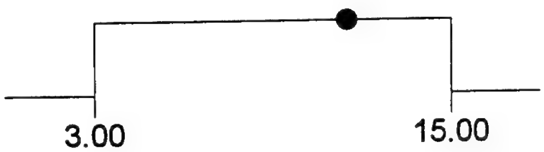

DESIGN-EXPERT Plot
Actual Components:
X1 = FCS
X2 = OS
X3 = HCS
Actual Constants:
H2O = 68.54
Expansion ratio
5.41829
4.6004
3.78252
2.96463
2.14674
X3 (20.46)
X1 (1.00)
X2 (10.00)
X2 (27.46)
X3 (3.00)
X1 (18.46)



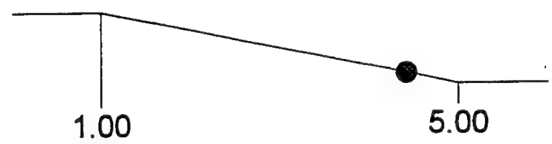
H2O = 68.55



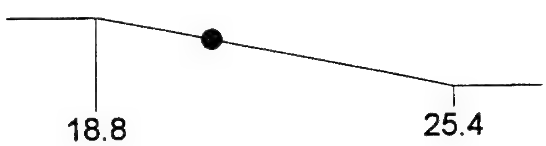
OS = 15.54



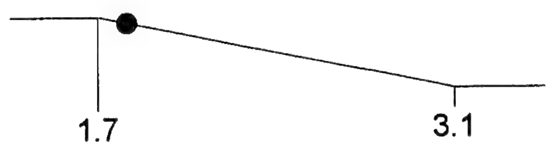
HCS = 11.48



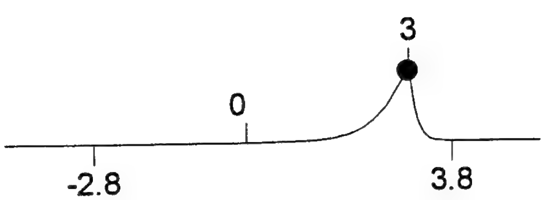
FCS = 4.42



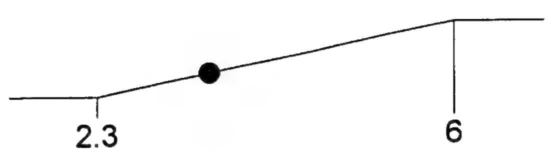
Surface tension = 20.9176



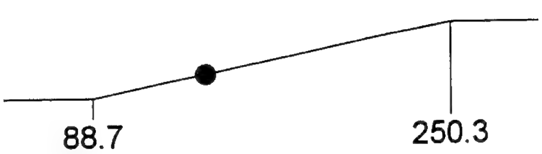
Interfacial tension = 1.81316



Spread Coefficient = 2.97982



Expansion ratio = 3.4662



Drain time = 138.996

Desirability = 0.488

Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight
H2O	60.00..75.00	60	75	1	1
OS	10.00..34.00	10	34	1	1
HCS	3.00..15.00	3	15	1	1
FCS	<= 1.00	1	5	1	1
Surface tensio	<= 18.8	18.8	25.4	1	1
Interfacial tensi	<= 1.7	1.7	3.1	1	1
Spread Coeffic	= 3	0	3.8	5	5
Expansion rati	>= 6	2.3	6	1	1
Drain time	>= 250.3	88.7	250.3	1	1

Solutions

	H2O	OS	HCS	FCS	Surface tensio	Interfacial ten	Spread Coeffi	Expansion rati	Drain time	Desirability
1	68.55	15.54	11.48	4.42	20.9176	1.81316	2.97982	3.4662	138.996	0.488

1 Solutions found

Starting Points

H2O	OS	HCS	FCS
60.56	25.54	8.91	5.00
64.93	22.96	7.12	5.00
60.59	25.45	9.12	4.84
74.65	13.65	6.70	5.00
64.60	30.01	3.00	2.39
60.00	27.18	8.84	3.97
67.05	18.20	13.24	1.51
75.00	16.04	7.96	1.00
61.90	33.62	3.29	1.19
60.03	20.21	14.82	4.94

DEVELOPMENT OF A GUIDANCE LAW USING OPTIMAL CONTROL THEORY

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August 1998

THE DEVELOPMENT OF A GUIDANCE LAW USING OPTIMAL CONTROL THEORY

Taylor L. Hughes
Niceville Senior High School

Abstract

The development of an optimal controller used for missile guidance was studied. Calculus of variations, basic missile guidance, and optimal control theory were all thoroughly researched so that a guidance law could be generated. Design methodology was agreed upon along with the system's complexity. Dynamics equations were produced and tested for controllability in the beginning of the process. The dynamics were linearized and then solved for using the method of linear quadratic regulators and transition matrices. The optimal controller was derived and identified.

Missile guidance is a rapidly expanding field in modern engineering. The need for more accurate munitions is inherent in modern warfare. With a premium on life, modern warriors must devise new methods to strategically destroy military targets without endangering innocent civilians. As was seen in the Gulf War, the weapons that have already been developed are many times more accurate than their predecessors were, but with new types of munitions being developed every year, more advanced techniques and technology are needed to guide these weapons to their targets.

Major advances in the capabilities of current and soon to be developed targets are placing significant demands on new tactical guided missiles. Missiles are not only needed to attack stationary ground targets, highly maneuverable, accelerating, air targets must be considered as well. Modern short range air-to-air missile engagements are the most critical scenarios. This is due to several factors including relatively short time intervals, sometimes on the order of two to five seconds, and the rapidly changing kinematics of the situation. These missiles need a high probability of a kill so that they can become a new wave of fire-and-forget weapons when deployed against intelligent maneuvering targets. Major improvements are being implemented, and are being developed with new guidance laws and hardware. Advancements in hardware are being applied to missile guidance systems very regularly. With high speed, large scale digital logic circuits, new, more advanced guidance laws can be programmed into the weapon's guidance package without much loss of performance from reduced fuel-mass.

(Need to change this sentence, or paragraph.)Stiff guidance requirements of extreme accuracy are met with rapidly evolving control design techniques. From its beginnings with the primitive Lark guided missile following World War II, missile guidance has now evolved into a mathematical world of complex differential equations (Zarchan ix). The target/missile kinematics are governed by a nonlinear geometric relationships, and therefore are described by nonlinear equations. Massive amounts of mathematics are needed to describe the missile's dynamics and an even more advanced computation is needed to create a guidance law that will direct the missile to its target. Not only are multiple differential equations needed for this process, but a more advanced mathematics is needed to create a guidance law. This mathematics is the calculus of variations. Developed in the late 17^{th} century by Queen Dido of Carthage, Johann and Jacob Bernoulli, Newton, and L'Hospital, the calculus of variations became a necessary tool for engineers and physicists (Kirk 107). The calculus of variations has supplied a way to explain dynamics in a more elegant

way with the LaGrange equations, along with providing a way to minimize functionals. Before these methods are expounded upon it is necessary to explain the outcome, namely, the guidance law.

A guidance law is an equation that directs guided munitions toward their targets. The guidance system inside the missile reads in data from its radar and sensor equipment and makes certain calculations based on its body orientation, closing velocity to the target, range, pitch rate, inertial acceleration, environmental conditions, and any other variable that the guidance law needs for computation. Then it processes all of these variables according to the programmed guidance law. This is done at each time interval throughout the missile's flight time. As slight variations occur with changes in the missile's dynamics, or with any changes in the target's states, feedback is sent to the guidance system which, according to the guidance equation, commands the missile to maneuver accordingly. The feedback in most situations is proportional feedback which estimates how far off target the system is and then sends a control command to the actuators to produce the desired outcome. This produces a closed-loop system which allows the missile to operate autonomously (Ogata 4).

Perhaps one of the simplest, and most known guidance law is proportional navigation, which is described by the equation (Zarchan 18).

$$u = NV_c\dot{\lambda} \tag{1}$$

In this equation u is the acceleration command, N is a constant gain implemented by the missile designer, V_c is the closing velocity of the missile to the target and $\dot{\lambda}$ is the line-of-sight rate of the missile to the target. The purpose of this technique is to drive the line-of-sight-rate to zero so that the two objects will collide, and thus, minimize their distances. This guidance law is used for constant velocity missile-target scenarios in which the missile operates only at small angles of attack. Although very useful in many situations, proportional navigation lacks the complexity that many modern munitions need to operate effectively and to their full potential in an accelerating engagement situation. That is why the necessity arises to create newer and more advanced guidance laws that are general in nature, yet can be adapted to any type of specific missile without a loss of accuracy and efficiency. Problems do arise, however, with any increase in complexity.

An increase in accuracy and precision also adds an element of complication to the system. An advantage of proportional navigation is that it is easily implemented with current sensor and radar

technology, and the onboard calculations of the guidance processing equipment are extremely simple. However, as was stated earlier, proportional navigation will not work in every circumstance. An obvious conclusion would be to increase the range of situations in which proportional navigation can work by adding extra terms that will guide the missile through accelerating combat engagements. This was done by a law that is known as augmented proportional navigation, and is represented by the equation

$$u_m = NV_c\dot{\lambda} + \frac{Nu_t}{2} \tag{2}$$

where u_m is the acceleration command for the missile, and u_t is the target's acceleration. This law is also widely used, and easily implemented, however is still inaccurate in situations where there is a copious amount of movement. This forces one to formulate a new guidance law that balances complexity with accuracy. This task is not as easy as it first seems because there are many things to consider when creating a guidance law.

The process of generating a guidance law is a tedious task that takes hours of work and thought. When the idea for the equation is still in its primordial stage it is important to consider many complications that may arise if the process is not planned well. First it is important to have a specific goal in mind. Most naturally this goal is to analytically (as opposed to numerically) solve a system of dynamics for a feedback control law that will minimize the miss-distance of a guided weapon in as many situations as possible with only the information provided by the missile's sensors, radar, and other easily implemented data links. As easy as it may sound, it is a most taxing operation. Once the objective has been set, a method for reaching this goal must be intuitively developed.

The method of developing the guidance law varies in difficulty as it proceeds. Much of the difficulty can be avoided if everything is planned out properly. It is not as hard a task if the proper coordinate system is chosen, and the proper constraints are defined, so that the math is not nearly as hard to solve as it would have been. The process consists of devising a set of differential state equations that describe the dynamics of the system that is to be controlled, and then solving this system of equations according to some set conditions while minimizing a set performance index. In order to fully understand this process, it is necessary to lay the basic foundation for this area of mathematics, calculus of variations and optimal control theory.

Optimal control theory stems from the fundamental concepts of the calculus of variations. To comprehend and utilize the valuable mathematics in optimal control theory, its foundation and roots in variational calculus must be explored. Calculus of variations is nothing more than a branch of math that determines the most extreme values or states of a functional[1] (Gelfand 2). It uses a certain penalty on the outcome, differential constraints, and boundary conditions to formulate the method of solution. The typical problem involves finding the minimal time, length, or energy for some functional J which is expressed by Eq. (3). Calculus of variations easily lends itself to the field of optimal control because it contains the mathematical architecture and machinery that optimal control needs in order to find the optimal controller u.

Missile guidance is a problem of optimal control, and optimal control is highly dependent on performance indices. A performance index is just a measure of the state of something or how much it has changed that indicates in a mathematical way how well the system is "performing" (Kirk 10). It is a mathematical equation or set of equations, that delineate the variables and states to be minimized. On occasion, certain state variables can be of conflicting nature, and weights are employed on the performance index to denote the more costly penalty on the specific state variables. An optimal controller's, or in this case, a missile guidance law's, purpose is to minimize or maximize some given performance index. The performance index is usually quadratic in nature and is most often represented by some function of the form

$$J = h(\mathbf{x}(t_f), t_f) + \int_{t_0}^{t_f} g(\mathbf{x}(t), \mathbf{u}(t), t)dt \qquad (3)$$

where t_0 and t_f are initial and final time respectively, h and g are both scalar functions, $x(t)$ are the state variables, and $u(t)$ is the control signal. The objective in optimal control is finding an admissible control $\mathbf{u}^*$ (an admissible control is one that satisfies the control constraints over the entire time interval $[t_0, t_f]$) which causes the system

$$\dot{\mathbf{x}}(t) = \mathbf{a}(\mathbf{x}(t), \mathbf{u}(t), t) = f(\mathbf{x}) + g(\mathbf{x})u \qquad (4)$$

[1] A functional is not a function, a functional is a relation that assigns a real number to each function belonging to some class.

where f is the drift vector of the state variables $\mathbf{x}$, and $\mathbf{g}$ is the control efficiency matrix on the control, to follow an admissible trajectory $\mathbf{x}^*$ that minimizes the performance measure Eq. (3) (Kirk 11)[2]. In order to solve this problem analytically many calculations and tests must be performed.

These calculations vary from simple matrix algebra to solving of non-linear systems of differential equations. In order to start it is necessary to generate a system of state dynamics in vector form that describe the physical system to be controlled. Once the dynamics have been generated it is necessary to test this system for controllability. This is a long,0 drawn out process that concerns generating a Jacobian matrix from the state equations and using Lie algebra to determine the Lie products $ad_f^i\mathbf{g}$ of the system where $i = 1,2,...n-1$, n is the number of state equations, and g is the control influence matrix which premultiplies the control u. This process reveals if all of the chosen states can be controlled or if they cannot be controlled and become unstable. If this test reveals that the system is uncontrollable it may be necessary to create a new system of dynamics that are controllable in order to proceed, depending on whether the uncontrollable subsystem is internally stable, and whether control of these states is important to the designer. If the test is a success then the next step is to begin solving the system.

There are many ways to go about solving a system of differential equations in order to produce a guidance law. Some of these methods include singular perturbation theory, reachable sets analysis, quasi-optimal control, dual control, and differential game theory. However, in relation to the missile guidance and optimal control techniques that were used in this project, one method stands out more than the rest. This method is that of Linear Quadratic Regulators (Linear Quadratic Regulators are the same thing as linear regulators only with a quadratic performance index). The method of solving LQR problems is a direct result from the work of R. E. Kalman (Kirk 209). The plant, or system, is described by linear state equations

$$\dot{\mathbf{x}} = \mathbf{A}(t)\mathbf{x}(t) + \mathbf{B}(t)\mathbf{u}(t) \tag{5}$$

that may have coefficients that vary with time, and the performance index (Kirk 209) is:

$$J = \tfrac{1}{2}\mathbf{x}^T(t_f)\mathbf{H}\mathbf{x}(t_f) + \tfrac{1}{2}\int_0^{t_f}[\mathbf{x}^T(t)\mathbf{Q}(t)\mathbf{x}(t) + \mathbf{u}^T(t)\mathbf{R}(t)\mathbf{u}(t)]dt \tag{6}$$

[2] Eq. (4) assumes that the system in question is time-invariant and affine in the control

The interpretation of this performance index is of a process whose minimization will drive a state vector as close as possible to the origin with a penalty on the control signal so that an excessive amount of control is not used. To solve this problem, the Hamiltonian of the system must be derived along with a set of costate equations. Then the transition matrix Φ must be solved for the states **x**(t) and the LaGrange multipliers (costates)**p**. Once this is completed a matrix **K**(t)will have been determined, yielding a feedback solution of the form

$$\mathbf{u}(t) = -\mathbf{R}^{-1}(t)\mathbf{B}^{T}(t)\mathbf{K}(t)\mathbf{x}(t) \tag{7}$$

(Kirk 211). Eq. (7) represents the optimal controller in terms of the state variables, the gain matrix that was computed, and the weighting matrices. The only thing left to do now is to test out and evaluate the guidance law.

The testing process can be done in one of two ways. The most difficult, most expensive, and most impractical way to do this would be to program the guidance algorithm into a missile's guidance processor and fire it in real-time at a target. Although this is eventually necessary, the most feasible way to initially test the law would be to create a simulation on the computer and run multiple tests to see how well the missile performs. Computer simulations do not have to be that complicated to get meaningful and qualitative results. It is only necessary to create a representation of the system using computer-aided design software such as Simulink™ and Matlab®. With these two useful tools a multitude of simulations can be created in a matter of minutes, and using this method, an easy simulation of a guidance law can be created in a short period of time. There are only a few steps that have to be taken to test the principle. The proper dynamics have to be programmed in and the gain matrix must be solved for numerically, however once these two operations have been completed, the simulation is very versatile. It can be used to track targets in any position using any degrees of freedom, any velocity, and any acceleration that the guidance law was designed to handle. Unfortunately, for the guidance law to work well in real-time situations it must be solved for analytically, and the only way to do this is by the previously described methods.

Once the method to be used has been thoroughly explained and understood, the process of developing a guidance law can be undertaken. Constructing the math model of the missile is perhaps the most intuitive step. This area requires a lot of engineering judgement that can drastically affect the outcome of the whole simulation, objective of the design engineer is to create an optimal system design that is not

too complex to solve analytically. The desired pin-point accuracy and real-life conditions add a large amount of complexity to the system that is usually not needed to such a precise detail. Usually it is safe to rely on some approximations that are based on valid assumptions to develop the model. The model can vary from a simple point mass treatment with only a few degrees of freedom, to a sixty-state problem with six degree of motion. With all of these choices available it was necessary to select a model that would be practical and feasible enough to implement on a missile. This is where my project began.

Perhaps the most important planning steps are to describe how the system will act, and what degrees of freedom it will be able to act in and then to describe the selected optimal control design methodology. The first process consists of developing system dynamics based on the degrees of freedom for the system. It was decided early on that the project would only have three degrees of freedom to simplify calculations. These degrees of freedom are the motions contained in the xz plane, which are pitching rotations up and down, and the motion of the closing velocity toward the moving target constrained to the vertical plane. Even with the motions simplified this much it would still take six equations to describe the system.[3] However using an inertial coordinate system with origin at the center of mass of the missile, and assuming that the speed of the missile is constant as well as the speed of the target, the system of equations can be reduced to four. This is possible because Eq. (1.1-1) from box 1.1 in the appendix represents the velocity in the y-plane and the velocity in the z-plane combined to form the range rate $\dot{R}$. The positions in the x and z directions are now measured by certain angular quantities and angular headings which transform the x and z positions into angular equations. It was necessary to create the system dynamics and then to express them in canonical form. These dynamics are first represented by the equations in box 1.1 in the appendix. The four equations had to be combined into a differential equation that could be solved for with the method of linear quadratic regulators. Once the dynamics were produced a system of equations had to be written so that the optimal controller could be described in terms of the differential equation. These equations are in box 1.2 in the appendix.

The problem now arises whether the system is actually controllable or not with all of the dynamic equations that need to be controlled so that the missile can be guided correctly. This is carried out through a procedure involving a specialized mathematical procedure using Lie algebra techniques. First the Jacobian

[3] The six equations are the position and velocity for each of the degrees of freedom.

matrix of f(**x**) from box 1.2 is taken and multiplied by the **g** matrix from those same equations to produce $ad_f\mathbf{g}$. This product is multiplied by the Jacobian two successive times to produce

$$ad_f^3\mathbf{g} \tag{8}$$

which is a necessity in the test for controllability. Once Eq. (8) is produced, it is analyzed to see if the control δ appears in this matrix. If it has not shown up, or it arose in the previous matrices first, then the system is said to be uncontrollable. Eq. (8) also has to be a matrix of full rank(four) because of the four differential system equations. If for some reason the matrix rank is less than four then some aspect of the system is uncontrollable.

Once the system was determined to be controllable it was time to solve this optimal control problem. As mentioned before, the methodology used was that of linear quadratic regulators. If this approach is taken, the performance index functional must be in quadratic form, the model dynamics of the missile must be in a linear, or a linearized form, and the constraints of the system can only be implicitly enforced by the performance index. To solve these types of equations several different paths can be taken. The two most popular ways are the sweep-back method, and the transition matrix method. The latter method is used here. For the control to be linked with, *R*, the range, *R* must be differentiated four times with respect to time to generate the **x** vector where

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} R \\ \dot{R} \\ \ddot{R} \\ \dddot{R} \end{bmatrix} \tag{9}$$

The dynamics of **x** are nonlinear, so in order to solve this system using LQR techniques it must be linearized first. $\dot{x}_4$ resembles a function $f + \mathbf{g}\delta$, where f is generally nonlinear, and can be easily linearized by transforming the form of the control input to be

$$\delta = \mathbf{g}^{-1}[\nu - f] \Rightarrow \dot{x}_4 = \nu \tag{10}$$

This substitution yields a linear differential equation

$$\dot{\mathbf{x}} = \mathbf{A}x + b\nu \tag{11}$$

along with a new performance index

$$\min J = \tfrac{1}{2}x_1^2(t_f) + \tfrac{1}{2}\int_0^{t_f} rv^2 dt \tag{12}$$

The Hamiltonian,

$$H = \tfrac{1}{2}rv^2 + \lambda^T(\mathbf{Ax} + \mathbf{b}v) \tag{13}$$

is generated and then subjected to the conditions of optimality. Once the conditions

$$\frac{\partial H}{\partial \mathbf{x}} = -\lambda \tag{14}$$

$$\mathbf{0} = \frac{\partial H}{\partial \mathbf{u}} \tag{15}$$

have been met, a transition matrix equation can be set up and solved for. The transition matrix equation

$$\begin{bmatrix} \mathbf{x}(t) \\ \lambda(t) \end{bmatrix} = \begin{bmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{bmatrix} \begin{bmatrix} \mathbf{x}(t_f) \\ \lambda(t_f) \end{bmatrix} \tag{16}$$

can then, by its definition, be manipulated into a more workable form of equation, which is represented by

$$\dot{\Phi} = \begin{bmatrix} \mathbf{A} & \mathbf{b}r^{-1}\mathbf{b}^T \\ 0 & -\mathbf{A}^T \end{bmatrix} \Phi with \Phi(t_f) = \begin{bmatrix} \mathbf{I} & 0 \\ 0 & \mathbf{I} \end{bmatrix} \tag{17}$$

Solving for the Φ_{ij} by the method of undetermined coefficients yields

$$\begin{aligned} \Phi_{11} &= e^{\mathbf{A}(t-t_f)} \\ \Phi_{12} &= (\mathbf{A} + \mathbf{A}^T)^{-1}[br^{-1}b^T e^{-\mathbf{A}(t_f-t)} - e^{\mathbf{A}^T(t_f-t)}] \\ \Phi_{21} &= 0 \\ \Phi_{22} &= e^{-\mathbf{A}^T(t-t_f)} \end{aligned} \tag{18}$$

Once this operation has been completed, the only thing left to do is to substitute Eq. (18) into Eq. (16) and solve for $\mathbf{x}(t)$ and $\lambda(t)$. This procedure produces

$$\mathbf{x}(t) = \{e^{-\mathbf{A}(t_{go})} + (\mathbf{A} + \mathbf{A}^T)^{-1} br^{-1}b^T[e^{-\mathbf{A}(t_{go})} - e^{\mathbf{A}^T(t_{go})}]p_f\}\mathbf{x}(t_f) \tag{19}$$

$$\lambda(t) = e^{\mathbf{A}^T(t_{go})} p_f\{e^{-\mathbf{A}(t_{go})} + (\mathbf{A} + \mathbf{A}^T)^{-1} br^{-1}b^T[e^{-\mathbf{A}(t_{go})} - e^{\mathbf{A}^T(t_{go})}]p_f\}^{-1}\mathbf{x}(t) \tag{20}$$

(where p_f are the LaGrange multipliers evaluated at t_f and $t_{go} = t_f - t$).

The controller can then be represented as a function of $\lambda(t)$ as shown by

$$\mathbf{u}(t) = -r^{-1}b^T e^{\mathbf{A}^T(t_{go})} p_f \{e^{-\mathbf{A}(t_{go})} + (\mathbf{A}+\mathbf{A}^T)^{-1} b r^{-1} b^T [e^{-\mathbf{A}(t_{go})} - e^{\mathbf{A}^T(t_{go})}] p_f\}^{-1} \mathbf{x}(t) \quad (21)$$

However the equation for the controller is still much more complicated because $\mathbf{x}^T = [R \quad \dot{R} \quad \ddot{R} \quad \dddot{R}] = f(R, \sigma_v, \alpha, q)$.

Now once the controller has been created, the question arises about what to actually do with it. The controller (21) represents a linearized feedback and control law used to guide a missile to its target using data about its range, body orientation, and pitch-plane motion, with respect to the target to make calculations. These calculations are fed directly into the control system which drives the aerodynamic or propulsive actuators that apply forces and moments to correct the missile's direction and velocity. This guidance law is unique in this regard, since nearly all previous guidance algorithms issue acceleration commands which must then be processed by a separate control system(or autopilot) which determines the appropriate commands to the actuators. Soon the value of this controller will have to be tested through rigorous computer simulations that calculate its abilities and weaknesses. It will be interesting to see how the guidance law performs in these situations considering the fact that it is already integrated into its control system. In order to evaluate its merit, the dynamical model must be programmed into a computer, along with the values of all of the constants. Then to find meaningful results, the system must be solved numerically many times to determine its full potential.

The development and testing of a guidance law is not an easy task, and is a very difficult area of engineering. It is a field that is filled with equations and computer programs, but like all areas of science, it has its own aspect of majesty. To think that every analytical solution to these dynamics equations yields another guidance law is astounding. Just by making minute changes to the system, and assuming different conditions, a new controller can be generated. There are an infinite variety of guidance laws that have not even been solved for yet, because of the enormity of the options. Just by using the dynamics described here and by making different assumptions, changing the degrees of freedom, or even the boundary conditions, one can affect the solution of $\mathbf{u}(t)$, and therefore, produce a new guidance law. The idea of the uniqueness of each solution and doing something that has never been done before is what draws many engineers to this field of study.

Missile guidance represents one of the great achievements of modern engineering. From its conception in the 1940's, it has grown to be one of the more popular fields of modern warfare engineering. This growth largely relies on the government's need for high-speed, effective, and accurate munitions that cost as little as possible. With the advancement of technology providing a means for these criteria to be met, new guidance laws must be constructed to utilize the abilities and adaptations of all of the advanced hardware material. This is the only way that modern combat can evolve into a tactical war where few or no innocent civilians are harmed. From experiences in more recent wars, it is this fault that has caused the most problems for the soldiers, and the political entities running the wars. So, any method that would reduce civilian casualties is pursued to its fullest extent. Now, since missile guidance is nearing its peak hardware performance with the available technology, the only thing left to improve missile accuracy is to invent an optimal guidance law. It is this task that engineers all over the world are working on today, and it is an engineering field that has improved the harsh conditions of modern wars, and has metamorphosed war from massive destruction, into the engagement of a string of prioritized targets that are destroyed to disable the enemy. It is this transformation of war that has made enhanced missile guidance so popular and useful. Once it has been realized to its full potential, missile guidance will continue to change the style of warfare for centuries to come.

Appendix

*Box*1.1

$(1.1-1)\dot{R} = -V\cos\sigma_v$

$(1.1-2)\dot{\sigma}_v = \frac{L_\alpha \alpha}{mV} - \frac{V\sin\sigma_v}{R}$

$(1-1.3)\dot{\alpha} = q - \frac{L_\alpha \alpha}{mV}$

$(1-1.4)\dot{q} = \frac{M_\alpha}{I_y}\alpha + \frac{M_q}{I_y}q + \frac{M_\delta}{I_y}\delta$

*Box*1.2

$$(1-2.1)\dot{\mathbf{x}} = \begin{bmatrix} -V\cos\sigma_v \\ \frac{L_\alpha \alpha}{mV} - \frac{V\sin\sigma_v}{R} \\ q - \frac{L_\alpha \alpha}{mV} \\ \frac{M_\alpha}{I_y}\alpha + \frac{M_q}{I_y}q \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{M_\delta}{I_y} \end{bmatrix}\delta =$$

$f(\mathbf{x}) + g(\mathbf{x})\delta$

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A STUDY OF WIND TUNNEL TEST PROCEDURES

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Final Report for:
High School Apprenticeship Program
Air Force Research Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

And

Wright-Patterson Air Force Base

August 1998

A STUDY OF WIND TUNNEL
TEST PROCEDURES

Joshua B. Jamison
Dixie High School

Abstract

The study of aerodynamics on airplanes is becoming more crucial in design and the methods of testing new models are advancing to meet those needs. I spent most of my research time working with a new method that dealt with the use of pressure sensitive paint. This method allowed us to see millions of pressure points on the model, rather than just a few hundred points, which was a maximum with the older method of using pressure taps to measure atmospheric pressure at certain points on the model.

A STUDY OF WIND TUNNEL TEST PROCEDURES

Joshua B. Jamison

Introduction

The study of how airplanes and other flying objects operate in motion and how to better develop these devices has been a question ever since the Wright brothers successfully made the first manned flight. It is only suitable that the same city that Wilbur and Orville Wright called home would be the same city of one of the largest design and testing facilities for new generations of airplanes. I was fortunate enough to have spent my summer working at Wright- Patterson Air Force Base and learning how the technology of testing future model planes has advanced and what the basics of aerospace engineering are. By being able to change designs and take accurate data from a model is very cost efficient and allows for many different variations on the same model in a relatively short time to see the effects of different variables.

The most standard method of determining pressures and loads on models is to use pressure taps and measure the atmospheric pressure through transducers. By examining the data from the transducers, engineers can then determine the stress at certain points on the model and determine if the model would be considered a potential candidate to be put into production or if the model needed major improvements or scrap the whole project.

Discussion of Problem

The problem with the older system of using pressure taps to measure lift and drag and et cetera could be very inaccurate or very time consuming in set up. On preliminary tests, small amounts of taps are used to cut back on the time to set up the model. The problem with this is that readings from other areas on

the wing surface are not taken and very damaging or substantial results cannot be taken. On the other end, if you want to take pressures from a hundred points on the wings, a hundred little plastic tubes have to be sent through the model fuselage and then each connected to a separate transducer. This is very time consuming along with locating blocked tubes once the model is totally assembled.

With every model that is tested, the test engineers and scientists almost always learn something new about airflow and pressures. Most of these discoveries are made when they examine the data and see something totally unexpected, and then have to carefully investigate why it did what it did, which takes even more time.

Methodology

Chemists who made a substance that gives off photons when certain wavelengths of light hit the paint thought of the approach to this problem. This paint also increases photon emission as the amount of oxygen is present, and photon emission decreases as oxygen decreases. This is the substance that we experimented with on models during my internship.

The light emitting devices required to excite the paint were previously only available through a select number of camera and scientific instrumentation companies. Along with the scare availability, the price of each light was between eight and ten thousands dollars a unit, and the wind tunnel tests would have required between ten and twelve for a bare minimum. A couple of these lights were purchased the summer before and an electrical technician/engineer ran tests on the intensity, stability, and other variables crucial to the testing procedures. He found the lamps to have a very long warm up time and have unstable wavelengths. He decided to experiment with Light Emitting Diodes (LEDs) because they are know to have a very small fluctuations in the light output and the warm up is very short compared to the larger lamps. The only problem was being able to mount enough LEDs in a concentrated region to produce enough intensity to excite the paint.

I worked on this problem during a mentorship last year, and we resolved the problem by designing

a circuit board which could hold eighty-eight LEDs and fit into a two inch copper coupling. We made these lamps, excluding the circuit board and LEDs, through parts that were readily available in our building. We ran experimental tests, like with the other lamps, and found these to be extremely effective in all the aspects we were looking for. The electrician then began to solder each of the eighty-eight LEDs onto a total of twelve circuit boards for all of the lamps. This was a very time consuming process considering how each LED had to cut and then soldered on individually. We analyzed the cost of making the lamps and figured the cost to be around a thousand dollars, with about four hundred in parts. We also decided to install manual irises in case we needed to limit the amount coming from certain lamps, and it proved to be very beneficial to our wind tunnel test.

We then mounted all the lamps directly above the upper windows of the test cabin and we also placed four lamps on a 45-degree angle to the model to shine on the side regions of the fuselage section. The model was then coated with the pressure sensitive paint and we then began to align and adjust the amount of light using the computer-controlled cameras. When the amount of photons coming off of every region only varied by a small amount, we began our tests.

The tests were going rather well as we swept through several different angles of attack to really see some dramatic results. However, during one of the angle changes, the whole sting support that is shaped like a big crescent, jumped off the bearing tracks and the hydraulics pumps could no longer move the model. Upon further investigation, the engineers realized that the bearings had worn a deep grove into the precisely manufactured crescent, so the test was finished and the process of trying to get the model support repaired began. We still ran a few more tests, but we were limited to only the one angle due to the fact that we did want to cause more damage than was already there.

By using a specific kind of light as a stimulus in our experiments, any stray light, such as the sun would render much of our information worthless. The tunnel we used had two open ends, and was not self contained. We noticed from some of the first tests that the sun coming out behind clouds was a major problem for our test. The intensity nearly doubled when the sun was completely out compared to the conditions we wanted. Running the tunnel at night or early morning was looking like our only choice, but

if the tunnel runs at night, a steady stream of fog or rain will be in the test due to the low dew point. After hearing that, we threw that idea by the wayside. We explored all the options we had and decided to run in between 11:00am and 2:00pm so the sun would not be shining directly into either end of the tunnel. One of the computer programmers then wrote a program that could sort through the pictures and automatically discard pictures with too much intensity.

Conclusion

By the time that I had finished my internship, only a few of the several hundred images had been translated into useful information. These few images did show the type of information we had hoped for, with pressure data form literally millions of points on the wing surface. We had planned many other things for our tests, but with the unexpected mechanical failure, we were unable to complete them.

A WEBPAGE FOR MNAL

Ryan A. Jones

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Final Report for:
High School Apprenticeship Program
AFRL/Wright Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

And

Wright Laboratory

August 1998

A Web Page for MNAL

Ryan A. Jones

ABSTRACT

A publicly accessible world wide web page was constructed for the Lethality and Vulnerability Branch. This web page provides the public, as well as the Department of Defense with useful information about the branch. The web page gives MNAL the capability to interact more effetely with the military and public communities. This capability will prove invaluable in today's information age atmosphere.

The site was constructed using several software packages. Netscape Composer was the primary construction tool. The Windows text editor Notepad was used for specific editing of the HTML source code. Paint Shop Pro was used specifically for developing and editing graphics.

The Air Force Research Laboratory has several regulations that all lab web pages must comply with. These regulations include a navigational side bar, a uniform background image, and regulations on the load time of a page. As long as the regulations are met, each web page can have its own look. The purpose of the regulations is to provide a common look and feel among all AFRL web pages.

A Munitions Directorate web page can not be released until it passes a public affairs approval procedure. The purpose of this procedure is to insure that all data being released has been approved for public release. The approval procedure will also insure that no false information is released. Branch approval, division approval, AFRL regulation approval, chief scientist approval, and Public Affairs Office approval are the five main steps in the approval procedure.

After the web page has been approved and is on-line, it must be maintained. The data on the page should reflect any changes taking place inside the branch. As new projects or testing take place, the web page should provide updated information about those programs. A web site with out dated information is virtually useless to the viewer. The web page will be a success if it provides useful information to those who whew it.

A WEB PAGE FOR MNAL

Ryan A. Jones

Since its development in the early 1990's, the World Wide Web has exploded in both commercial and private growth. In 1992 there were 50 recognized web sites on the Internet. As of January 1998 there were approximately 2,450,000 web sites. Many companies and organizations are now using the web as a focal point for distributing information about their products and services. Web sites allow anyone with Internet access the opportunity to obtain a multitude of information about a countless number of subjects.

The goal of this project was to design and construct a publicly accessible web site for The Air Force Research Laboratory, Munitions Directorate, Lethality and Vulnerability Branch. The web site was to be stored on a personal computer until approval through the public affairs procedure. Once approved the web site would be uploaded to the Munitions Directorate's public access web server. Once on-line, the site would be viewable to any one in the world with Internet access.

It is important for the Lethality and vulnerability Branch to have a web site for several reasons. The web site allows for easy public distribution of information about the branch. Any one in the general public can learn about different programs and testing going on inside the branch. Department of Defense organizations and contractors will have easy access to specialized data, which may be pertinent to their mission. Much of the work done in the Lethality and Vulnerability Branch is not similar to any other DoD organization. With a web site, this specialized information will be readily available to everyone. Military cut backs are a constant worry among today's military community. A web site allows for top military officials to see what functions are being carried out in specific organizations. This could reduce the chances of that organization being eliminated. Finally, the web site will allow prospective engineers the opportunity to learn about the various types of engineering work being done by the branch.

Although virtually no restraints were put on the method of development, the Air Force Research Laboratory has certain criteria that must be adhered to by all lab web sites. In order to reduce load time, no high intensity graphics could be used. AFRL requires that no web page take longer than one minute to load on a 28.8 modem. Even in the age of high-speed digital Internet connections, some people still use slower modems thus increasing the load time of a web page. It was decided that because of this fact, no advanced java script or CGI

script would be used. Users with older browsers such as Netscape 2.0 are not able to view newer versions of java and CGI. A uniform background image should appear on all Directorate web pages. A background image is a picture that appears behind the text and graphics of a web page. Finally, an AFRL standard side bar must be on the opening of any branch web site. This side bar contains links to the Air force Research Laboratory's main page as well as other useful information such as a dictionary and an internal search engine.

Installing the side bar created a unique challenge. The side bar is made with an HTML, HyperText Markup Language table. The side bar is a table that occupies the left one-forth of the browser window. Small image icons are arranged vertically down the screen. Each image has text describing the location of its link. Netscape Composer, which was the primary software used for the construction of the site, was unable to insert the bar into a blank page so another web editor was used. Notepad, is a common windows based text editor that can be used for editing HTML source code. Unlike Netscape Composer, which allows for point and click web editing, Notepad requires the use of the direct HTML source code. Although not as user friendly, Notepad allows for fine-tuning of the final product. For example, data can be manipulated more precisely using the Notepad interface. To remedy the side bar problem, the code for the bar was copied from another Directorate web page. It was then inserted into the Lethality and Vulnerability Branch page using the cut and paste options. Once this was complete all the external links were checked to insure the integrity of the side bar. After its installment, the side bar requires no further modifications.

Generally, the first step in constructing a web site is the construction of the main or opening page. This is the first page that will appear when a user accesses the site. The main page is usually like a table of contents. It provides links to various other pages on the site. The standard AFRL side bar occupies the left-hand portion of MNAL's main page. The right hand segment contains the body of the page. At the top is a title in large font displaying the name of the branch. Beneath the title are the names of the Branch Chief and Technical Advisor. Since the page is public accessible, the names of the other members of the branch were not posted. A small photograph of a test item is located just below the names of the branch chief and technical advisor. Interesting pictures on the main page grab the attention of viewers. The next item that was added was the mission statement. This is a short declaration of the purpose and mission of the Lethality and Vulnerability Branch. The mission statement gives a

reader a brief description of the function of the branch. The remainder of the main page is divided into two sections. The first section contains links to the Target Modeling and Simulation Team and the System Effectiveness Team. The second section contains links to information about the different technology areas the branch is currently using. Instead of using plain text to denote these two sections, it was decided that a small graphic would be more appealing. A simple colored dividing bar was downloaded from the Internet and Paint Shop Pro was used to enlarge it and add text to it. Finally, the branch address and phone number, as well as the email address of the Branch Chief appears at the bottom of the page. This general contact information provides a viewer with the ability to contact the branch for questions or comments.

The Target Modeling and Simulation Team page has several features. Along with a team mission statement there are two links. The "Test Photos" link points to a page where a user can view from a variety of pictures. These pictures show different tests that the team has done. The other link points to a page about MEVA.

MEVA or, Modular Effectiveness Vulnerability Assessment, is a major project of the Target Modeling and Simulation Team. The page contains a list of project objectives and requirements that was obtained from a CD-ROM. There is also a section of the page containing movies and photos. Several power point slides depicting different examples of MEVA in use were converted into JPG format. A movie, which shows screen shots of the program in use, is available for instant viewing or downloading. Also obtained from the MEVA CD-ROM was an Adobe Acrobat file. This file, which is in pdf format, contains a technical overview of how MEVA works. The file was originally eight mega-bytes in size. It was determined that the file should be reduced in size because of the huge amount of time it would take to download it. The pdf file was zipped up using Winzip 32, a free software package that allows for zipping and unzipping of files. After a file has been zipped, it is smaller in size than its original version. In this case the file size was reduced from eight Megs to three Megs. This decreases the download time by more than fifty percent. Along with the pdf file is a link to the Adobe Acrobat web site. A user can download a free copy of the Adobe Acrobat Reader, which must be used to view pdf files.

The rest of the MNAL web pages are similar in layout to the pages described above. As many pictures as possible were added to keep the page interesting. There are also two navigation links at the bottom of each page.

One sends a user back to the MNAL main page and the other sends a user to the Munitions Directorate main page. The purpose of these links is to provide easy navigation from page to page.

The process of building a Munitions Directorate web page is not over when the construction of the page is completed. All web pages must be subjected to a public affairs approval procedure. The approval process consists of five main parts. First, the branch chief must review the page. He will check to insure the validity of all the information on the page. Once approved by the branch chief, the division director will then review the page. He will also check for correctness of data a
s well as checking to insure that all data and photos are cleared for public release. The page is then sent to the branch in charge of maintaining the web server. They will check to see if the page meets the AFRL requirements. The chief scientist will then review the page looking for mistakes and information that may be sensitive. The final hurtle of a web page is the Public Affairs Office.. They do a final check to insure that no data or pictures are classified or sensitive. They also review the professionalism of the page. Once the page has been approved, it will then be uploaded to the Munitions Directorate web server.

Even when a page is finally on the web, it still must be maintained. The key to having a useful web page is having current information. Organizational and management changes are constantly taking place in the military. The web page should reflect any changes that may occur. Many projects and programs are also rapidly changing. To be useful, a web page should have the most up to date and correct information as possible. This requires constant updating and modifying of the page.

The Lethality and Vulnerability Branch now has an easily accessible web page. They now have the capability to publish information to millions of people as well as to interact with outside people via electronic mail. Now that the web page has been established, it will be easy for someone to update it as needed. The Lethality and Vulnerability Branch has now entered a new era in communication and commerce. A plethora of opportunities may open up for both the branch, and the public.

Welcome to the Lethality and Vulnerability Branch (MNAL)

Branch Chief - Major Peter Hanlon, Ph. D
Technical Advisor - Mr. Ron Hunt

Mission Statement:

To perform engineering based munitions effectiveness assessments of advanced and conceptual weapons against ground-fixed, mobile\relocatable, air and space targets.

TEAMS

- [illegible]
- [illegible]

TECHNOLOGY AREAS

- Penetration
- Blast
- Shock
- Fragmentation

- Synergistic Effects
- Target Modeling
- Target Fragility

For more information about the branch, please send e-mail to: Major Peter Hanlon hanlon@eglin.af.mil *or call (850) 882-2579 x3251*

Assessment and Demonstration Division Page

A WEB PAGE FOR MNAL
RYAN A. JONES

Target Modeling and Simulation Team

Mission:

To develop, validate, and maintain predictive models for accurately assessing existing and emerging conventional weapon system damage mechanisms against ground fixed, mobile/relocatable, air, and space targets.

Models

- MEVA

Testing

- Selected Photos

[illegible]

Return to Munitions Directorate

Modular Effectiveness Vulnerability Assessment

Objectives

- Develop a data flow programming software environment for specifying, executing and visualizing the results of vulnerability assessment simulations.
- Develop weapons effectiveness modules for this environment.

Requirements

- Data flow programming editor
- Modules that implement EVA 3-D functionality
- New vulnerability assessment algorithms
- Configuration management procedures and software

Movies and Photos

Photos

test1.jpg
test10.jpg
test13.jpg
test17.jpg
test19.jpg
test32.jpg
test35.jpg

Movies

mevasample.avi *(3.3 MB Windows movie)*
[illegible] *(1.8 MB Windows movie)*
[illegible] *(1.2 MB Windows movie)*

Technical Information

Download meva.zip (3.1 MB) PDF file containing technical and operational information about MEVA

CLICK HERE to download Adobe Acrobat Reader for viewing PDF files.
NOTE : These software links are to non-Government sites and are for information only; they do not represent an endorsement by the Department of Defense or the U.S. Air Force.

Selected Photos

FILE NAME	SIZE	DESCRIPTION
bef-gun.jpg	158 KB	Ballistic Experimental Facility (BEF) Gun Range 40 mm gun
befgun-2.jpg	158 KB	BEF Gun Range - 50 cal gun
[illegible]4.jpg	153 KB	Fluid Circuit Breaker on Test Stand
jig-use.jpg	121 KB	Impact Test Positioning Device
[illegible]2.jpg	108 KB	Component Blast Test - Pre Test
[illegible]	145 KB	Component Blast Test - Post Test
drumtest[illegible].jpg	92 KB	55 gal Drum Test at SWRI FaBallistic Range

[illegible]

Return to Missions Directory

Multiple studies at Wright Patterson Air Force Base

Kevin Katerberg

Dayton Christian High School

Final Report for:
High School Apprentice Program
Wright Patterson Air Force Base

TRF

and

CARL

August 1998

Multiple studies at Wright Patterson Air Force Base

Kevin S. Katerberg
Dayton Christian High School

Abstract

For the first part of my summer here I worked with Jess Underwood on some odd jobs that he had piled up for someone to do. The main project that I did with him was to program an automatic dialer, which in the cause that an alarm for overheating or an alarm for humidity should go off this system would dial numbers of the people of people who would then come in and fix the problem. This project proved to be very tedious since alarms would sound even though there was no reason for the alarms. After two weeks of working on this project I was shifted to a different project.

This project was to test a compressor fan blade to fin its resonance frequency and its modes. On this project I worked as on team with Ailean Gracia so the report on that was written up on her computer so I am just able to put a copy of it in this report. The report for this project starts on page 3.

After completing that project I moved on to a project about the aerodynamics of a cooling fan blade. I tested a fan blade to find how the air circulates after coming off the blade. A short report follows on page 14

Modal Analysis for CRFER II Rotor Blades

Aileen J. Garcia and Kevin S. Katerberg
31 July 98

Wright Patterson Air Force Base
Dayton, Ohio

TABLE OF CONTENTS

ABSTRACT

All objects want to vibrate at their natural frequencies. The purpose of this experiment was for three reasons, 1.) To determine the natural frequencies of a CRFER II Blades, 2.) To compute and plot the several mode shapes of a CRFER II Blades by exciting the blades, and 3.) To compare the data taken from the Air Force Lab to the data taken by GE. To conduct this experiment six CRFER II Rotor Blades were tested for modal analysis.

This experiment involves the use of the BOBCAT System as well as the STAR Program, in which the data collected from the blades were analyzed. The transfer functions were represented as graphs in the BOBCAT System. After the graphs were displayed, the data collected was transferred to STAR. The results achieved in this experiment were higher than the usual frequencies found in a rotor blade.

INTRODUCTION

Background

Modal analysis is a method in which one can test an object to find the strengths of its structural design and dynamics. During modal analysis the natural frequencies can be found. Through the data collected in a modal analysis experiment, one can derive models to represent the object's structural dynamics. The results can also provide problems with the object, as well as the dynamic behavior of the object during its performance time.

Research Objectives

The purpose of this experiment is to determine the dynamic properties of six similar CRFER II blades. Particularly, the purpose for this experiment are the following:

1. To determine the natural frequencies of a CRFER II Blades.

2. To compute and plot the several mode shapes of a CRFER II Blades by exciting the blades.

3. To compare the data taken from the Air Force Lab to the data taken by GE.

Research Summary

Six CRFER II Blades previously tested by GE are reexamined to check if the modal analysis is a sufficient method of discovering the resonance of a compressor blade. Each CRFER II Blade is held in place with a metal blade holder which is held in place with an anvil. An

accelerometer is attached to the same position on each blade that is tested. To excite the blade, a small hammer with a force transducer attached was also connected. Both the force transducer and accelerometer are connected through the amplifier to the BOBCAT System. In the BOBCAT System, the computer displayed each transfer function in which ten averages were taken. After the data was collected, it was transferred to the STAR Program.

The STAR System allows the data collected in the BOBCAT System to locate all the modes. To locate the modes the geometry of the object has to be defined. It automatically analyzes a data set after the measurements are taken. STAR then, provides an animation of the object vibrating at the modes.

TESTING

Testing Specimen

Six CRFER II Blades from a rotor were used as the test specimen for this investigation. The six blades were assigned specific numbers depending on its position in the rotor. The following blades were tested:

Blade 1
Blade 8
Blade 16
Blade 24
Blade 32
Blade 40

A coordinate graph was used to determine the various points for exciting the CRFER II Blades. The origin could be found at the corner of the base line on the leading edge. The points were numbered vertically beginning with 2 as the origin and ended with point 25 which was at the top corner of the trailing edge.

The height of the blade from its origin on the leading edge is 4 inches, and 2.9167 inches on the trailing edge. It's width measured from the top of the blade is 3.567 inches and .1167 inches in its center at the top of the blade. The Leading and trailing edges of the blades has a thickness of .0167 inches. Refer to Figure 1 in the Appendix.

Test Apparatus

All tests were conducted at Wright Patterson Air Force Base in Building 252, Area B. For the experiment the blades were mounted onto a solid metal block and clamped into an anvil. An accelerometer was attached next to the base of the leading edge by a piece of wax. A hammer and accelerometer were connected to the Bobcat System

through an amplifier. The hammer was equipped with a force transducer.

In the BOBCAT System a graph of each transfer function was displayed on the screen. Ten excitation averages were taken for each of the twenty four data points. For this system, there was an auto range which displayed the different levels of hits. A red flag would come up if the hit was too strong, a green for a reasonable range, and yellow for a weak hit. The BOBCAT System automatically rejected all double hits as well as overloaded hits.

Test Procedure

To conduct this experiment the first step was to measure each blade for the grid. With chalk identical grid lines were drawn vertically and horizontally. At the points where the lines meet, each point was given a specific number. All of the numbers were in numerical order and began with two and ended with twenty-five. Refer to Figure 2. The first point, two, was located at the bottom near the base of the leading edge. The last point, twenty-five, was located at the top, closest to the trailing edge.

When all the grids were drawn, the next step was to measure each point for its x, y, and z position. Refer to Table 1 in the Appendix. The x direction was perpendicular to the y axis. The y axis was parallel to the face of the blade, and z axis was the height of the blade.

When all the measurements were taken the next step was to mount the blade onto a solid metal block. Then the block was placed in an anvil and tightened. A piece of was used to connect the accelerometer to the blade. After the accelerometer was attached, the BOBCAT System was turned on and the besting began. Refer to Figure 3 for a similar test setup.

To do this test, the auto range was used to determine how strong each excitement had to be. Then the double hit was turned on so the computer would not accept any type of hit besides single hits. Each point was then excited until it reached ten averages. When all twenty-four points were completed the data was transferred to the

STAR Program. All of the blades were excited before using the STAR Program.

Data Reduction

When the testing was complete in the BOBCAT System, all of the data was transferred into the STAR Program. In the STAR Program, the first step was to define the geometry. To define the geometry, all the measurements from the second step was translated and inputted into the computer. The STAR System was used to display the data from the BOBCAT System. The first step in this system was to input the geometry of the blade. The equations for the x and y axis were translated and the equation used was as follows:

$$x^* = \frac{(x - y)}{\sqrt{2}} \qquad\qquad y^* = \frac{(x + y)}{\sqrt{2}}$$

After the geometry was defined, the next step was to identify the modes. To do this six bands around the major peaks were placed in the same area for the different graphs. Each band represented a mode. The next step was to look at each mode shape for each blade. Before viewing each mode auto fit was selected for each blade. Then a display of each structure was observed to describe the shapes of the modes.

RESULTS

Discussion of Results

In the structure setup two displays of the blade were shown. The first, trace A, was a model of the mode shapes when it was deformed. In the second, trace B, the model of an undeformed blade. The two traces displayed the movement of the blade in trace A each how much the points shifted between trace A and trace B. There were three types of mode shapes that were found in the blades, rigid body, bending, and torsion. Rigid body modes caused the entire blade to shift for its original position, which is very unlikely to occur in actuality. The bending modes had two different kinds, first bending modes and second bending modes. In bending modes the object is fixed at the base and the top moves back and forth. The torsion modes had only one kind of torsion in this experiment, first torsion modes. First torsion modes cause the blade to move in a twisting manner.

The first mode that is usually found in modal analysis is usually the first bending mode. The second real mode is usually the first torsion mode. After these two modes the rest of the modes can be bending or torsion modes, or even a mix between these two types of modes. For this experiment the first two real modes were the first bending and first torsion. The other modes were mixes between first torsion and second bending or second torsion modes.

The frequency at the first real mode of the blades is approximately 800Hz. This is not normal for the first real mode in modal analysis because the first real mode is usually about 600Hz. Refer to Table 2 through Table 7 for Frequency Results and Picture 1 through Picture 36.

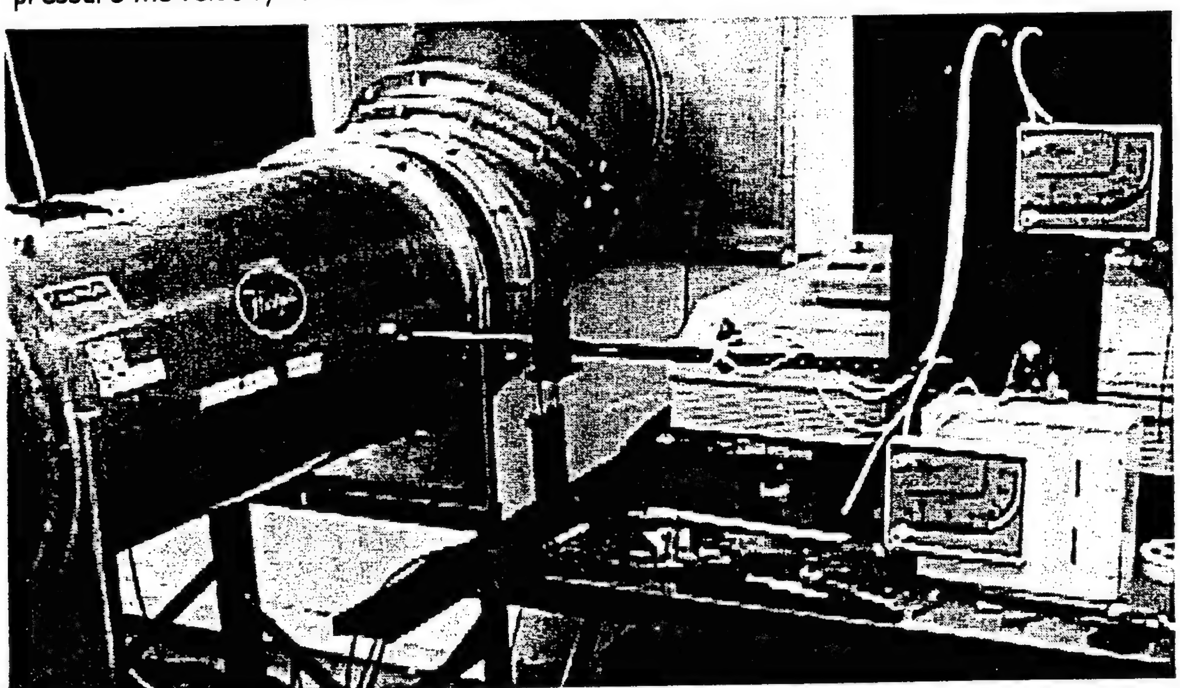
BLADE NUMBER	MODE	MODE SHAPE	FREQUENCY (Hz)
1	1	RIGID BODY	95.52
	2	RIGID BODY	272.56
	3	1^{ST} BENDING	799.54
	4	1^{ST} TORSION	2.04e+3
	5	2^{ND} BENDING & 1^{ST} TORSION	2.57e+3
	6	2^{ND} BENDING & 1^{ST} TORSION	4.01e+3
8	1	RIGID BODY	95.52
	2	RIGID BODY	272.56
	3	1^{ST} BENDING & 1^{ST} TORSION	799.54
	4	1^{ST} TORSION	2.04e+3
	5	2^{ND} BENDING & 1^{ST} TORSION	2.57e+3
	6	2^{ND} BENDING & 1^{ST} TORSION	4.01e+3
16	1	RIGID BODY	95.52
	2	RIGID BODY	272.56
	3	1^{ST} BENDING	799.54
	4	1^{ST} TORSION	2.04e+3
	5	2^{ND} BENDING	2.57e+3
	6	1^{ST} TORSION	4.01e+3
24	1	RIGID BODY	95.52
	2	RIGID BODY	272.56
	3	1^{ST} BENDING	799.54
	4	1^{ST} TORSION	2.04e+3
	5	2^{ND} BENDING	2.57e+3
	6	1^{ST} TORSION	4.01e+3
32	1	RIGID BODY	95.52
	2	RIGID BODY	272.56
	3	1^{ST} BENDING	799.54
	4	1^{ST} TORSION	2.04e+3
	5	2^{ND} BENDING	2.57e+3
	6	2^{ND} TORSION	4.01e+3
40	1	RIGID BODY	95.52
	2	RIGID BODY	272.56
	3	1^{ST} BENDING	799.54
	4	1^{ST} TORSION	2.04e+3
	5	2^{ND} BENDING & 2^{ND} TORSION	2.57e+3
	6	1^{ST} TORSION	4.01e+3

Error Analysis

In this experiment the frequency was much higher than the frequencies that one would normally expect in this situation. The frequency that is normally expected for the peaks is around 600Hz, but it ranged up to about 800Hz. One thing that probably caused this was the blade setup. Instead of holding the blades in place the way they are normally held in a rotor it was held in place by bolting it to a solid metal block which was secured in place with an anvil. Another thing that might have caused some of the error is that the metal disk that sits between the blade and the metal block did not fit right so it got bent up when the blade was tightened into place.

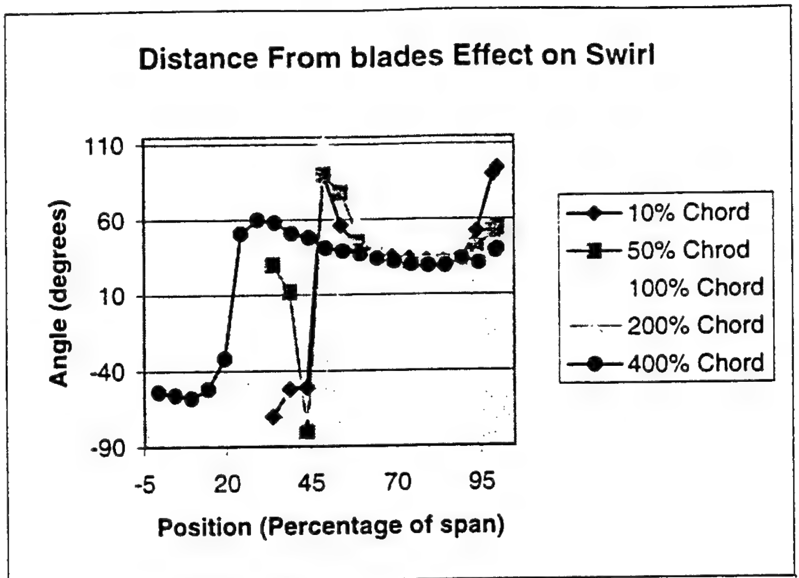
Some of the blades were eroding or slightly deformed. This was not supposed to be a problem in the testing, but these features must be considered when the values taken are compared to the expected values.

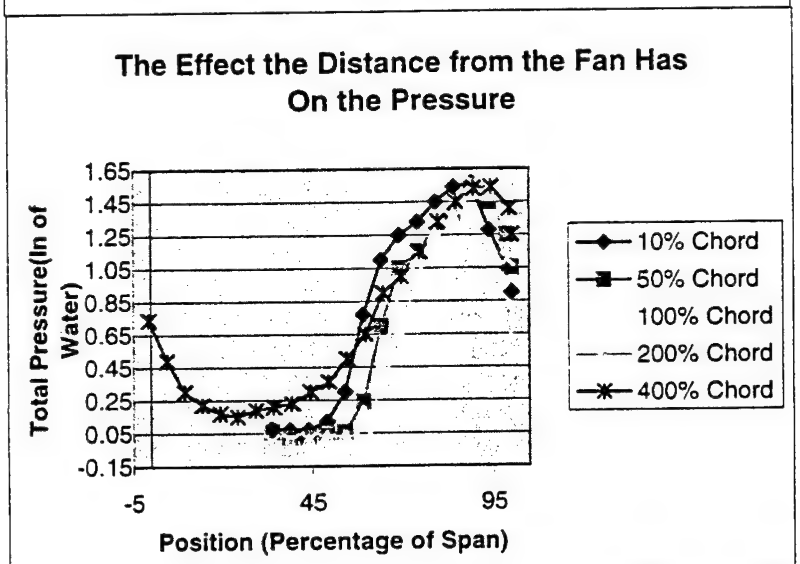
After completing that project I was moves to a different section of the base at which I worked On finding the pressure, the velocity, how air swirled after it passed through a cooling fan from a Jeep Cherokee, so that ITT can better design these fans for the Jeeps. To test the fan we mounted the fan on a motor, which we then controlled by remote control. The motor was housed in a large metal tube just larger than the fan. For our test we used a wedge probe, which has a one tap in the front of it and one on each side. Manometers are hooked up to each of the taps. The center tap, if compared to normal atmospheric pressure and it find the total pressure. The taps on the two sides of the wedge were compared to each other and by turning the probe to face the wind could null the probe, meaning that then the probe was facing directly into the wind. When it was nulled the angle at which it nulled was recorded. After it was nulled the one side would then get opened to atmospheric pressure so that the pressure reading now became the static pressure. By use of a rather simple formula using the total pressure and the static pressure the velocity of the air can found.

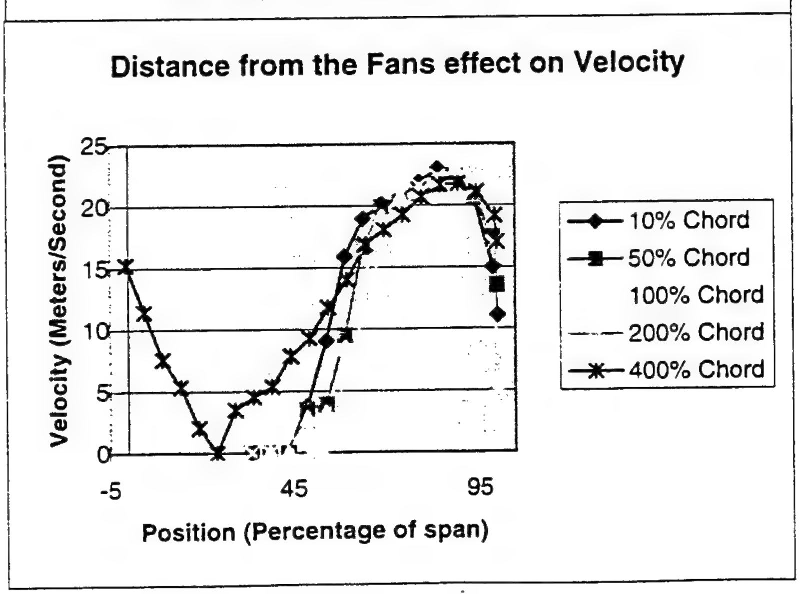


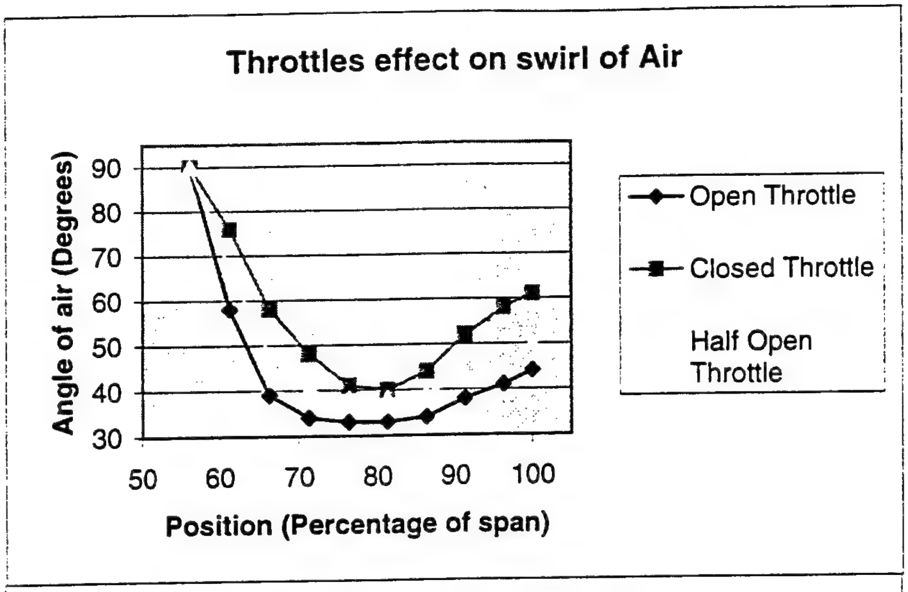
This is a picture of the test setup. On the left side of the picture is the test chamber. In it is the fan itself, which is connected to the motor, which is also housed in this metal tube. At the back of the tube a metal rod comes out that rod is part of the wedge probe which is currently at the back of the housing. To the right of the housing and along the metal rod is a black box this box tells what angle the probe is facing. On the right side of the picture are two manometers, which give us the data we need.

The test was done at different speeds and data was taken at multiple locations along the length of the housing. Graphs of the data follow.

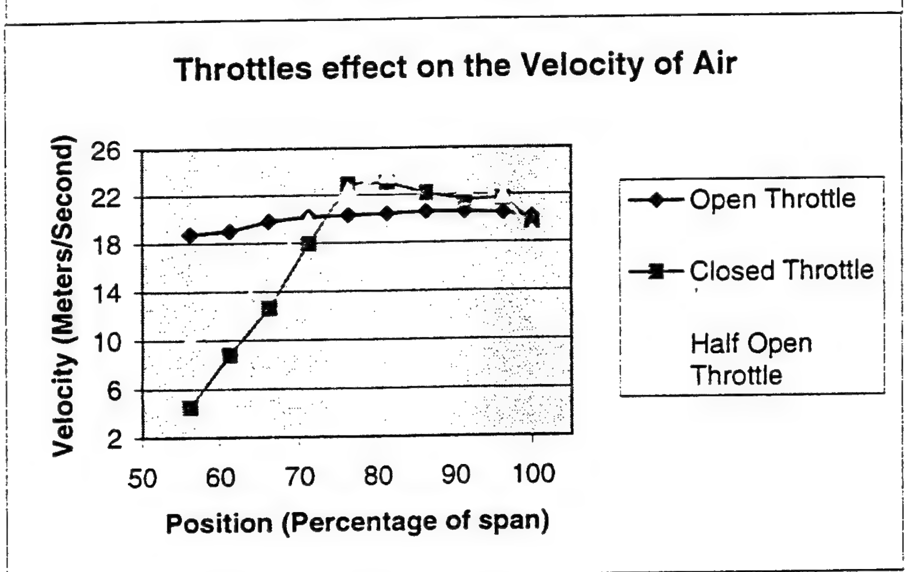

Distance From blades Effect on Swirl
110
60
10
-40
-90
Angle (degrees)
-5
20
45
70
95
Position (Percentage of span)
10% Chord
50% Chrod
100% Chord
200% Chord
400% Chord


The Effect the Distance from the Fan Has On the Pressure
1.65
1.45
1.25
1.05
0.85
0.65
0.45
0.25
0.05
-0.15
Total Pressure(In of Water)
-5
45
95
Position (Percentage of Span)
10% Chord
50% Chord
100% Chord
200% Chord
400% Chord

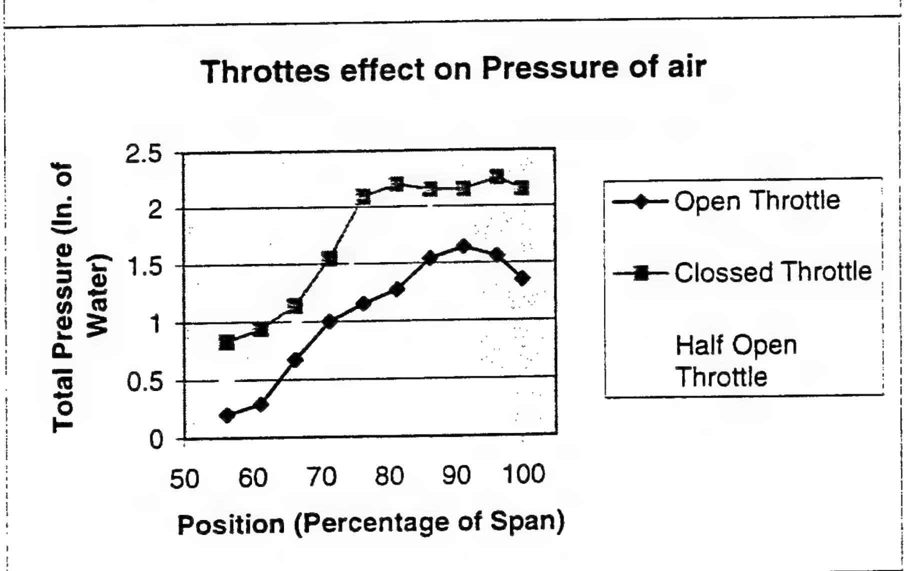

Distance from the Fans effect on Velocity
25
20
15
10
5
0
Velocity (Meters/Second)
-5
45
95
Position (Percentage of span)
10% Chord
50% Chord
100% Chord
200% Chord
400% Chord



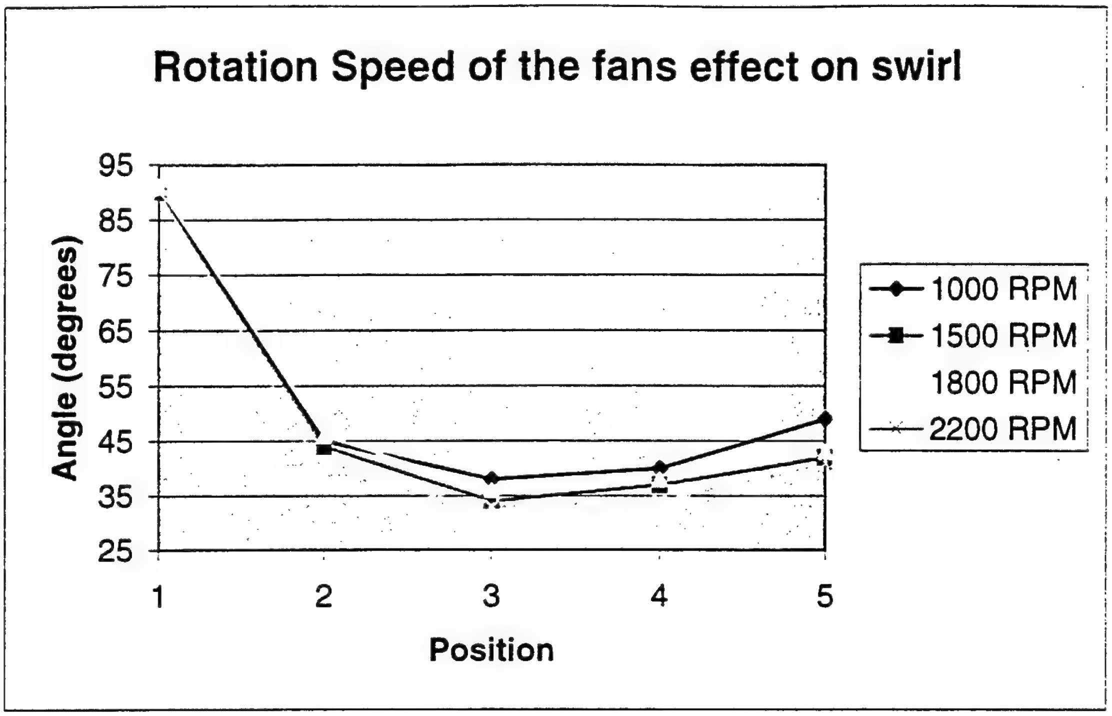
Throttles effect on swirl of Air
Angle of air (Degrees)
90
80
70
60
50
40
30
50
60
70
80
90
100
Position (Percentage of span)
Open Throttle
Closed Throttle
Half Open Throttle

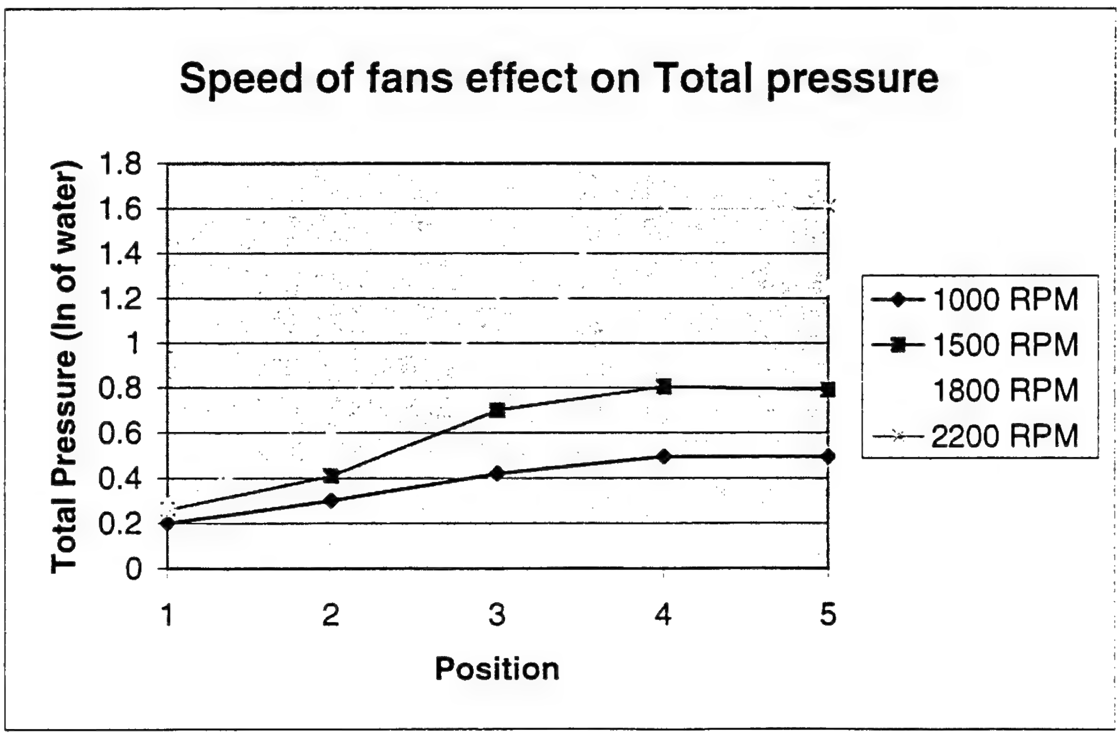


Throttles effect on the Velocity of Air
Velocity (Meters/Second)
26
22
18
14
10
6
2
50
60
70
80
90
100
Position (Percentage of span)
Open Throttle
Closed Throttle
Half Open Throttle



Throttes effect on Pressure of air
Total Pressure (In. of Water)
2.5
2
1.5
1
0.5
0
50
60
70
80
90
100
Position (Percentage of Span)
Open Throttle
Clossed Throttle
Half Open Throttle


Rotation Speed of the fans effect on swirl
Angle (degrees)
95
85
75
65
55
45
35
25
1
2
3
4
5
Position
1000 RPM
1500 RPM
1800 RPM
2200 RPM


Speed of fans effect on Total pressure
Total Pressure (In of water)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
Position
1000 RPM
1500 RPM
1800 RPM
2200 RPM

THE DEVELOPMENT OF A SEARCH ENGINE FOR AN INTRANET

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The Development of a Search Engine
for an Intranet

Joseph M. Kesler
Carroll High School

Abstract

The work done this summer consisted of learning the Perl scripting language and then using it to devise and write a search engine for an intranet currently being developed. The first part of the work this summer was reading and studying books on Perl and CGI scripting. In addition to this, learning the UNIX operating system was a requirement, as was achieving a basic understanding of HTML. Once a basic knowledge of the Perl language was attained, basic programs were written in order to become familiar with syntax, structures, and the like. After a short time, work on a basic skeleton engine was begun, which later developed into the engine now in place.

The Development of a Search Engine for an Intranet

Joseph M. Kesler

Introduction

Today, the Perl language has become a critical element in the development of the Internet, and along with that any kind of dynamic net. Perl allows simple development of CGI scripts--programs, set to run behind what is seen, that keep nets from being completely static. CGI scripts also play a phenomenal role in all nets today--that of search engines. Search engines are one major driving force in nets today in that they can search through everything on a net and pick out exactly what the user wants to look at. They are critical time savers as people do not have to sift through all of the pages out there. However, search engines also take much time and patience to develop, as they must be able to pick out what the user wants in a relatively short amount of time. There is also no set way to create an engine, but this leaves a sort of artistic freedom for the programmer.

Discussion of Problem

The problem to be solved was to devise and write a search engine that could be used to find pages that dealt with a particular topic residing within the directory structure of the ML research intranet. A previous search engine had already been set up to find and give information(set up in a database) on people who work in the directorate, but no engine had yet been developed to search for other HTML pages which were not a part of the database. Therefore, the final product was required to have the capability to search through the actual HTML of the pages to get information mandatory to the searching functions.

Methodology

As stated earlier, there is no set method for writing a search engine. Therefore, the methodology presented here is the process by which the search engine created this summer was designed while also incorporating a basic overview of the programs' operations. The actual functioning system is composed of three programs, one of which is the actual search engine. The other two programs were set to create index files for the search engine to peruse at runtime. Otherwise the engine would have to search through all of the HTML pages on the server while the user is waiting for a response. Because of the number of pages already created and the number that are still in process, this

would take up an inordinate amount of time (at the time of this writing, the whole process of searching and creating the index files takes over 20 minutes). This is definitely unacceptable for a program that is supposed to give some kind of response within a few seconds and not too much more. The two index-file makers were therefore set to run very early every morning in order to catch any possible updates to pages, additional pages, or deletion of pages. The first program, dubbed *resmaker* (see Appendix A), searches through the entire directory structure and writes to file the directory path of every HTML page. The program continues to sequentially open every HTML page and extract critical information from every page and write it to file in a special format that the search engine can understand. The program first retrieves the title of the HTML document and strips the HTML tags from it. It then pulls the keywords from the document that are contained in the META tags and then strips off the HTML. The final information the program extracts is the whole body of the text excluding tags. The program then prints to the file *isearch* the keywords followed by the title, to the file *bodysearch* the body followed by the title, and to the file *links* the title followed by an abbreviated directory path that is formatted to be printed as a hypertext link.

The second program, called *corrector* (see Appendix B), fixes flaws within the files created by *resmaker*. These flaws arise from a possible flaw within the programming which has yet not been discovered, or possibly a bug within the Perl language (it is possible as an updated list is kept at the Perl website). At any rate, this flaw produces a duplication of the last line written when the file is opened for appending. The program *corrector* removes this extra line which would otherwise reek havoc on the processes of the search engine. It operates by keeping a counter as it goes through each file and removes every third line, the duplication line as only two lines were written at a time in the previous program. These two programs were also written in Perl, but are not CGI scripts.

The final program of the three, called *infosearch .cgi* (see Appendix C), is the actual search engine. Its creation began with a simple skeleton program that could only print that it had found a match between a single word input and a single word resource file. The program grew quickly as experience was gained in writing Perl. Almost all of the major changes were written in the form of subroutines added onto the program and called from other places within it. This was done to make the code easier to read, correct, and append to. In reality, the program could have been written as one long program without much trouble at all, but the code would have been much more confusing and changes much more difficult to make (imagine 170 lines of straight code with no empty lines). Each separate subroutine performs a specific function inherent to its name.

The first order of business for the program when it is executed is to retrieve the input from whatever source is sending it, be it an HTML page or just from the command line. The program then calls the subroutine *converter* to perform several functions on the input, that of removing extra spaces, case conversion, punctuation removal, and converting the input into the format demanded by the module used in this program, CGI.pm. The input then is passed on to this module which breaks it apart and puts it into an array. The resulting array is then passed to the command import_names which places the input into a special name space, in this case R. At this point the input is ready to undergo the matching routine. However, the files created by the two preceding programs must be read into the search engine so that the information can be used to identify candidate HTML pages for the given input. This task is accomplished in the subroutine *reader* which sequentially opens and reads into an array the three files created by *resmaker*. After this is accomplished the next subroutine creates another associative array which is actually an inversion of the array links. This routine had originally been created to help in the printing the hypertext links, but it was found more useful in the searching routine.

The subroutine *tester* is the searching process which tests for pattern matches between the different parts of the HTML pages and the given input. Both sections of the routine are composed primarily of nested loops and conditional statements, at points up to 4 levels. The first section deals with the pattern matching between the input and the keywords from each HTML page, the keywords also including the title as not all of the pages had keywords previously incorporated. The second section of the routine deals with the pattern matching between the input and the body of the HTML pages. As this would take a great deal longer to complete as compared to a simple keyword match, this section was reserved for use only if the number of individual page hits was below a certain amount, the best number for that amount still being determined. At the time of this writing, the body would be checked if there were less than 4 pages found through keyword searching. And even that was restricted in the number of words the engine could read out, somewhere around 250 words. The results from both of these sections were stored in 2 associative arrays, one with keywords with a point value, the other keywords with a value of the title of the HTML page matched to. The point value aforementioned was a weighted value depending on the importance of a type of match. An exact keyword match was given a value of 14, a normal keyword match (a match that is not exact but matches a string i.e. pulse matching pulsed) was given a value of 7, and an exact match to a word in the body with a value of 2.

The next routine in the program orders the results from the routine *tester* by number of hits. This is to make the results given back to the user to be closer to how he/she wants them. The routine first takes the keywords from the associative array *resultcount* and places them into the array *switcher*. This array is then manipulated so that the keys become the values and the values become the keys. The keys of this new associative array are sorted and placed in another array. The sorting function, however, has to call another subroutine to help it. The sort function in Perl, when applied to a group of numbers, only orders according to the first digit in the number, then the next, until there are no more digits in a number. It does not use the number as a whole. The subroutine written for the sort compares the numbers as a whole and passes a value back to the sort function. This value helps the sort function order the entries correctly. Finally, the last array is created, composed of the original keys from the associative array *resultcount* but now sorted by the number of hits that their respective pages received.

The final routine of the program generates the return HTML for the user. It is set up basically just like HTML except that each HTML tag had to have a print command with single quotes so that the program itself would not try to interpret the tags but instead pass them on to the server. The section that creates the hypertext links is just a foreach loop calling values from the array ordered and uses them to print both the directory structure for the links and the titles for the HTML pages. A sample return page can be found proceeding the references section of the report.

Results

As of now, the engine is functional, but not quite completed. More work still must be done, mainly on the pattern matching routine and the return HTML. The pattern matching still has some flaws in it. As for the return page itself, only the basics have been implemented, such as a link back to home, a second search box, and the links. In addition the results given are not always the same. Sometimes links are duplicated or not given at all. But even with these problems, the search engine is still effective in its purpose.

Conclusion

In conclusion, the development of a search engine can at times take a lot of work and effort. However, it can also be fun and rewarding as one begins to see more clearly the direction the development is heading and can

therefore judge and implement better the changes and additions that need to be made. As it is difficult to give any type of scientific conclusion for this project, personally I'd like to say that I have definitely learned a great deal through this, especially in web development and in the programming area in general.

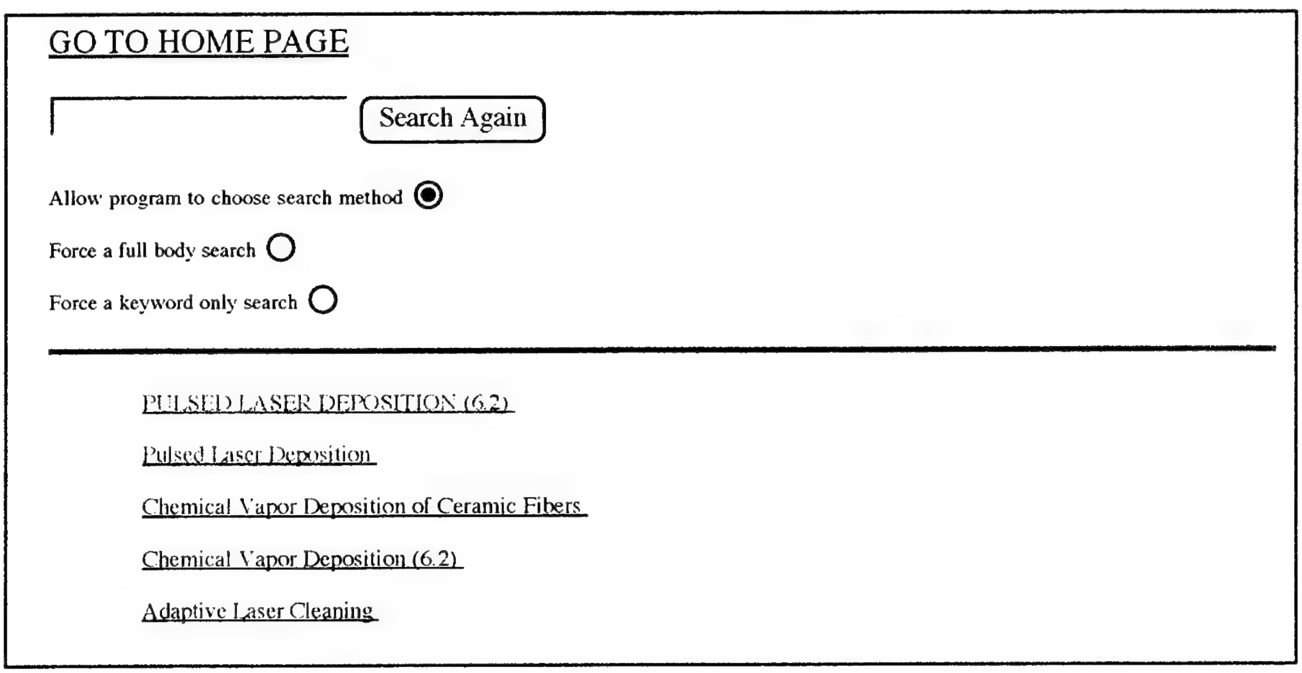
References

Graham, Ian S. HTML Sourcebook 2nd ed. New York: Wiley Computer Publishing, 1996.

Herrmann, Eric. teach yourself CGI Programming with Perl in a week. Indianapolis: SAMS.net Publishing, 1996.

Till, David. teach yourself Perl 5 in 21 days 2nd ed. Indianapolis: SAMS Publishing, 1996.

Sample return HTML page



NOTE: The programs are not syntactically correct due to formatting by Word.

resmaker Appendix A

```
#!/usr/local/bin/perl

system ("find /apps/ns-home/docs/ -name \*.html >dirstructure");

unlink isearch;  #gets directory paths for pages, deletes isearch

unlink bodysearch; #deletes bodysearch

unlink links;  #deletes links

open (STRUCTURE, "/apps/ns-home/cgi-bin/dirstructure"); #opens dirstructure

@pagedir=<STRUCTURE>; #reads each path into an element of pagedir

close <STRUCTURE>; #closes dirstructure

foreach $pagedir (@pagedir) { #reads out each path of pagedir

 $a="";    #resets all variables used

 $b="";

 @b="";

 $c="";

 @c="";

 $d="";

 @d="";

 $e="";

 $f="";

 $g="";

 $h="";

 $t="";

 $u="";

 $v="";

 $counter3="";

 $counter2="";

 $counter="";
```

```
$count="";
$z="";
$match="";
open (PAGE, "$pagedir"); #opens an html page
while ($a=<PAGE>) { #reads out each line of the page
 chop $a; #chops off the newline
 if ($a=~/\<TITLE\>.*/) { #checks to see if $a contains the title
  $b=$a; #reads a into b
  $b=~tr/</ /; #cuts out the brackets
  $b=~tr/>/ /;
  $b=~tr/\// /; #cuts out the slashes
  @b=split / /,$b; #splits the line into words
  $count=0; #resets count
  foreach $t (@b) { #reads out each element of b
   if ($t=~/TITLE/) {
    $t=""; #deletes t if it contains the word title
     }
   $b[$count]=$t; #reads t back into b
   $count++; #increments count
    }
  $e=join(" ",@b); #joins the elements of b into scalar e
  $e=~s/^[ \t]+//; #deletes space at the beginning
  $e=~s/[ \t]+/ /g; #deletes extra space within the title
 } elsif ($a=~/\<META.*/) { #checks to see if a contains meta tags
  if ($a=~/.*keywords.*/) { #checks to see if they are keywords
   $c=$a; #reads a into c
   $c=~ tr/\<,\>/ /; #removes brackets
```

```
  $c=~ tr/\=/ /; #removes equal signs

  $c=~ tr/\"/ /; #removes quotes

  @c=split / /,$c; #splits c into words

  $counter=0; #resets counter

  foreach $u (@c) { #reads out each element of c

   $u="" if ($u=~/META/); #deletes meta

   $u="" if ($u=~/keywords/); #deletes keywords

   $u="" if ($u=~/NAME/); #deletes name

   $u="" if ($u=~/CONTENT/); #deletes content

    }

  $c[$counter]=$u; #reads u back into c

  $counter++; #increments counter

   }

 } elsif (($a=~/\<BODY.*/)||($counter2==1)) { #checks to see if a contains the body of the HTML page

 $counter2=1; #sets counter2 to 1-this is for when the body tag is no longer contained in a

 $d=$a; #reads a into d

 $counter2=0 if ($d=~/\/BODY/); #resets counter2 if the end of the body is reached

 $d=~s/<.*>//; #deletes all HTML tags

 $d[$counter3]=$d; #reads d into array d

 $counter3++; #increments counter3

 }

$g=join(" ",@d); #joins elements of d into scalar g

$g=~s/^[ \t]+//; #removes beginning space

$g=~s/[ \t]+/ /g; #deletes extra space between words

}

foreach $z (@b) {  #reads out each element of b

$c[$counter]=$z; #reads z into array c
```

```
$counter++; #increments counter-this section reads the title into keywords
}
$f=join(" ",@c); #joins elements of c into scalar f
$f=~s/^[ \t]+//; #deletes space at beginning
$f=~s/[ \t]+/ /g; #deletes extra space between words
close <PAGE>; #closes the HTML page
unless ($match==1) { #part of deleted statements-don't fix if it isn't broke
 open (ISEARCH,">>/apps/ns-home/cgi-bin/isearch"); #opens isearch for appending
 seek (ISEARCH, 0, 2); #goes to end of isearch
 select (ISEARCH);
 $|=1; #makes program write directly to file, no buffer
 print ISEARCH ("$f \n"); #prints the keywords
 print ISEARCH ("$e \n"); #prints the title
 close <ISEARCH>; #closes isearch
 open (BODYSEARCH, ">>/apps/ns-home/cgi-bin/bodysearch"); #opens bodysearch
 select (BODYSEARCH);
 $|=1; #no buffer
 seek (BODYSEARCH, 0, 2); #goes to end of file
 print BODYSEARCH ("$g\n"); #prints body text
 print BODYSEARCH ("$e \n"); #prints title
 close <BODYSEARCH>; #closes bodysearch
  open (LINKS, ">>/apps/ns-home/cgi-bin/links"); #open links
 select (LINKS);
 $|=1; #no buffer
 seek (LINKS, 0, 2); #goes to end of file
 print LINKS "$e \n"; #prints title
 $pagedir=~s/\/apps\/ns-home\/docs//; #creates relative directory path
```

```
print LINKS ("$pagedir"); #prints link
 close <LINKS>; closes links
 }
}
```

```
#!/usr/local/bin/perl

open (ISEARCH, "/apps/ns-home/cgi-bin/isearch"); #opens isearch

@corrector=<ISEARCH>; #reads isearch into corrector

close <ISEARCH>; #closes isearch

open (ISEARCH,">/apps/ns-home/cgi-bin/isearch"); #opens isearch for writing

$count=1; #sets count to 1

$counter=0; #sets counter to 0

foreach $a (@corrector) { #reads out each element of corrector

 if ($count % 3) { #the duplicated line number is divisible by 3

  $fixed[$counter]=$a; #it therefore won't make it past the if statement

  $counter++;

 }

 $count++;

}

$fixed=join("",@fixed); #joins the elements of array fixed into scalar fixed

print ISEARCH $fixed; #prints fixed to file

close <ISEARCH>; #closes isearch

open (BODYTEXT, "/apps/ns-home/cgi-bin/bodysearch"); #opens bodysearch

@corrector=<BODYTEXT>; reads bodysearch into corrector

close <BODYTEXT>; #closes bodysearch

open (BODYTEXT, ">/apps/ns-home/cgi-bin/bodysearch"); #opens for writing

$count=1; #sets count to 1

$counter=0; #sets counter to 0

foreach $a (@corrector) { #reads out each element of corrector

 if ($count % 3) { #checks for every third line as before

  $fixed[$counter]=$a;
```

```
 $counter++;
 }
 $count++;
}
$fixed=join("",@fixed); #joins the elements of array fixed into scalar fixed
print BODYTEXT $fixed; #prints fixed to file
close <BODYTEXT>; #closes bodytext
    #the process just repeats
open (LINKS, "/apps/ns-home/cgi-bin/links");
@corrector=<LINKS>;
close <LINKS>;
open (LINKS, ">/apps/ns-home/cgi-bin/links");
$count=1;
$counter=0;
foreach $a (@corrector) {
 if ($count % 3) {
  $fixed[$counter]=$a;
  $counter++;
 }
 $count++;
}
$fixed=join("",@fixed);
print LINKS $fixed;
close <LINKS>;
```

```
#!/usr/local/bin/perl
use CGI; #loads the module CGI.pm
$input=<stdin>; #reads in the input from the query of the user
&converter; #runs the subroutine converter
$query=new CGI($input); #passes the input to CGI.pm
$query->import_names('R'); #assigns the values of the input returned by CGI.pm to the namespace R.
&reader; #calls the subroutine reader
&linkassist; #calls the subroutine linkassist
&tester; #calls the subroutine tester
&order; #calls the subroutine order
&linker; #calls the subroutine linker
sub converter {
 $input=~ tr/\t //d; #removes all spaces from the input
 $input=~ tr/A-Z/a-z/; #changes upper to lower case
 $input=~ s/%22//g; #deletes parentheses that were hex encoded
 $input=~ s/%(..)/&name=/g; #formats all other hex as +
 $input=~ s/\+/\&name\=/g; #converts plus signs into a format for CGI.pm to use
 $input=~s/\\,\!,\@,\#,\$,\%,\^,\(,\),\_,\-,\/,\|,\},\{,\],\[,\',\;,\",\:,\?,\.,\>,\,,\<,\`,\~//;
} #deletes all stray punctuation

sub reader {                    #reads a resource file into an array.
 if (open (SUBJECTLIST, "isearch")) { #opens index file isearch
  @subjectlist=<SUBJECTLIST>; #reads each line of the file into array subjectlist
  chop @subjectlist; #chops off the newline character
  %subjectlist=@subjectlist; #passes the array to the hash subjectlist
  close <ISEARCH>; #closes isearch
  }
 if (open (BODYTEXT, "bodysearch")) { #opens index file bodysearch
  @bodytext=<BODYTEXT>; #reads each line of the file into array bodytext
  chop @bodytext; #chops off the newline character
  %bodytext=@bodytext; #passes the array to the hash bodytext
  close <BODYTEXT>; #closes bodytext
  }
  if (open (LINKS,"links")) { #opens index file links
```

```
@links=<LINKS>;  #reads each line of the file into array links
  chop @links;  #chops off the newline character
%links=@links;  #passes the array to the hash links
close <LINKS>;  #closes links
};
}

sub tester {
while (($subject,$title)=each(%subjectlist)) { #reads the keywords to subject and the title to title
 @subject=split (/ /,$subject); #splits the keywords into single word elements
 foreach $subj (@R::name) {  #reads each element of R::name in turn into subj
  foreach $subject2 (@subject) { #reads each element of subject into subject 2 in turn
   $subject2=~ tr/A-Z/a-z/; #case conversion and punctuation removal
   $subject2=~s/\+,\&,\\,\!,\@,\#,\$,\%,\^,\(,\),\_,\-,V,\l,\},\{,\],\[,\',\;,\",\:,\?,\.,\>,\,,\<,\`,\~/ /;
   if ($subj eq $subject2) { #does a test for exact keyword match
    $resultcount{$subject}+=14; #if there is a match, a value of 14 is assigned


     }
   if  ($subject2=~/$subj/i)  { #tests  for  a  pattern  match
    $resultcount{$subject}+=7;  #if a match is found, a value of 7 is assigned
    $results{$subject}=$title;  #creates a hash of all matched pages
   }   #an exact keyword match will also have a pattern match
    }
   }
 }
@length=keys (%results); #reads the keys of results into length
$length=@length; #determines the length of length
if ($R::search eq body) {
          $R::search=program;
          $length=0;
}
if ($R::search eq program) {
if ($length<4) {  #tests to see if at least 4 pages have been found
  while (($subject,$title)=each(%bodytext)) { #if not a body match is performed
  $bodycount2=0; #resets the value of bodycount2, $subject is the body,
  @subject=split (/ /,$subject); #the body is split up into individual words
```

```
  foreach $subj (@R::name) { #the elements of R::name are read into subj
   $bodycount=0; #resets the value of bodycount
   foreach $subject2 (@subject) { #reads the elements of subject into subject2
    $subject2=~s/\+,\&,\\,\!,\@,\#,\$,\%,\^,\(,\),\_,\-,\/,\|,\},\{,\],\[,\',\;,\",\:,\?,\.,\>,\,,\<,\`,\~/ /;
    $subject2=~tr/A-Z/a-z/; #punctuation removal, case conversion
    $subject2=~s/[ \t]+/ /; #extra space deletion
    if ($subject2 eq $subj) { #performs an exact body match
     $keywords=$titlelist{$title}; #keywords contains the keywords for the title
     $resultcount{$keywords}+=2; #a value of 2 is assigned
     $results{$keywords}=$title; #the page is marked as matched
       }
       $bodycount++; #increments bodycount
    last if ($bodycount==250); #tests if 250 words have been checked
      }
   $bodycount2++; #increments bodycount
   last if ($bodycount2==100);
     }
     }
  }
 }
}
sub linker {
print "Content-type: text/html\n\n"; #prints the HTML header
print <<'end_print'; #the program will print exactly what follows until "end_print" is reached
<HTML>
<HEAD>
<TITLE>Search Results</TITLE>
<BASE HREF="http://ml-internal-rd.ml.wpafb.af.mil/">
</HEAD>
<BODY BGCOLOR="#FFFFFF" TEXT="000000" LINK="0000FF">
<FONT SIZE=+1><A HREF="/cgi-bin/index.cgi">GO TO HOME PAGE</A><P>
<FORM ACTION="cgi-bin/infosearch.cgi" METHOD="POST">
<INPUT TYPE="text" NAME="name">
<INPUT TYPE="submit" VALUE="Search Again">
<P>
```

```
<FONT SIZE=0>Allow program to choose search method <input type="radio" name="search" value="program"
checked>
<P>
Force a full body search <input type="radio" name="search" value="body">
<P>
Force a keyword only search <input type="radio" name="search" value="keyword">
</FORM>
<HR>
end_print #ends the exact printing

if (%results==0) {      #checks to see if no matches were made

print <<'end_print';
<H1>No Matches Found!<H1>
end_print
} else {

print '<OL>';
foreach $match (@ordered) {  #reads out each element of ordered
print "<FONT SIZE=-1><A
HREF=$links{$subjectlist{$match}}>$subjectlist{$match}</A>\n";
print '<P>';   #prints links with the title displayed
}
print '</OL>';
}
print <<'end_print';
</BODY>
</HTML>
end_print
}

sub   order   {
 foreach $b (keys(%resultcount)) { #reads the keys of resultcount into b
  $switcher[$count]=$b; #puts the keys into array switcher
  $count++;
  }
```

```
foreach $c (@switcher) {  #reads out each element of switcher
 if (defined($result{$resultcount{$c}})) { #checks to see if a point value exists
  $resultcount{$c}+=1 until ($result{$resultcount{$c}} eq "");
 }    #increments the point value until it is not defined yet
 $result{$resultcount{$c}}=$c; #creates an array of point values with titles as values
 }
@resultcount=keys (%result);  #reads the keys of result into resultcount
     @resultcount2= reverse sort sorter (@resultcount); #sorts resultcount into resultcount2 using sorter
foreach $d (@resultcount2) { #reads out each element of resultcount2
 @ordered[$e]=$result{$d}; #reads each element into ordered
 $e++;  #increments  e
 }
}
sub linkassist {
 @keywords=keys(%subjectlist);  #passes the keys of subjectlist to array keywords
 foreach $element (@keywords) {  #takes each element of keywords in turn
  $titlelist{$subjectlist{$element}}=$element; #creates a hash of the title with its value as the keywords
  }
}
sub sorter {
 $numa=$a;
 $numb=$b;
 $retval=$a<=>$b;
 $retval;
}
```

AN INTERFACE FOR THE AUTOMATED CONTROL OF HEAT TREATMENT FURNACES

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Final Report for:
High School Apprentice Program
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August 1998

AN INTERFACE FOR THE AUTOMATED
CONTROL OF HEAT TREATMENT FURNACES

Joshua M. Knopp
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Abstract

A program was written to monitor and control up to nine heat treatment furnaces at a time. The program can run each controller in one of two modes. In setpoint mode the controller utilizes fuzzy logic to approach and maintain a desired temperature. In program mode, the user may specify a set of up to six segments, consisting of a setpoint, ramp time, and dwell time. Each segment is then executed in sequence once the command is given. Graphs and log files were added for extensive monitoring capabilities. The bulk of the program is in linking the interface to the appropriate ASCII codes and floating-point or integer values. The program offers an effective, user-friendly interface for control of the heat treatment furnaces.

AN INTERFACE FOR THE AUTOMATED
CONTROL OF HEAT TREATMENT FURNACES

Joshua M. Knopp

Introduction

Heat treatment furnaces are used extensively in the ceramics division of the Materials and Manufacturing Directorate at WPAFB. The ability to maintain constant temperatures for extended periods of time with minimal deviation is invaluable to ceramics research, which often involves heating a material to a specified temperature to test changes in attributes such as strength. Some experiments may require a material to be heated to several different temperatures in sequence.

Discussion of Problem

The major drawback to most furnaces is that the very basic and sometimes unresponsive controllers are often discovered to be inadequate for many research projects. Writing and running segmented programs is particularly tedious and difficult. An interface that allows control of multiple furnaces from a single computer terminal is much more desirable.

Methodology

To solve the problem, a program was created using Labview v4.1, a graphical, C-based programming interface designed for the control of laboratory instrumentation. This allowed input from the front panel of the VI (Virtual Instrument) to be sent to a UDC (Universal Digital Controller) 3000 via serial port communications.

The first step was to establish communication with the controller. A series of reads and writes were performed to insure that the ASCII identification codes were being received and processed correctly, and that the appropriate integer or floating-point decimal was being returned. Then, a separate VI was created to handle all serial communications. The ASCII codes for each of the commands were indexed such that the main program is able to simply pass the desired controller number, command code, and write parameter (if applicable) to the subVI. The subVI in turn creates the appropriate six-term communication string and sends it to the controller.

Next, the main VI was created. The first command is a call to another subVI, 'Controller Initializer'. This VI attempts to initialize each of the nine controllers in either setpoint or program mode. If the controller cannot be initialized properly (i.e. the communication times out) the main program will disable and gray out that controller's display on the front panel. The problem may then be fixed and the controller will be re-initialized at the click of a button, which calls a modified version of the 'Controller Initializer' VI.

The main program loop begins with a comparison between the controls and indicators on the front panel and their corresponding global array elements. This detects any changes made since the last loop and stores them in global array 'Changes'.

The next step copies data from any controls which have changed to their respective global array elements, and copies global information into the appropriate indicators to update them.

For each controller, the global array elements are copied into temporary variables for easy reference. If necessary, a log file is created by a separate VI. This includes the furnace number, date, time, and an empty spreadsheet for time elapsed, current temperature, and current output power. The next portion of

the program, assuming the furnace has not timed out, performs all necessary communications with the controller, graphs and logs data from all furnaces being monitored, and updates the temporary variables. Also, the switch that toggles between setpoint and program modes is checked. If its state has changed, the proper commands are given to the furnace to change its mode. Setpoints can be modified from the front panel, and segmented programs are accessed and modified through a 'Segment Editor' VI.

After all communications are completed and all temporary variables are updated, the data is copied back into the appropriate global arrays. The program then waits five seconds (a span of time appropriate for monitoring) before repeating the main loop.

Results and Conclusion

The final version of the program is able to accomplish the desired goal - to monitor and control heat treatment furnaces in both setpoint and program modes. The interface is simple and user-friendly, and all reads and writes to the controller are handled appropriately. The program execution is noticeably slow, and the response times of some controls are very excessive.

In conclusion, while there is room for improvement, the program performs the desired operations simply and effectively. The goal to provide computer-based monitor and control of the furnaces has been accomplished.

References

Honeywell Inc., Universal Digital Controllers RS422/485 ASCII Communications Option Product Manual, 1997.

National Instruments, Labview 4.0 Online Reference, 1996.

A STUDY OF THE PREDICTION OF PILOT-INDUCED OSCILLATION

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Final Report for:
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August 1998

A STUDY OF THE PREDICTION OF PILOT-INDUCED OSCILLATION

John P. Lightle
Tippecanoe High School

Abstract

The phenomenon known as pilot-induced oscillation (PIO) was studied. Data from flight simulations by four different pilots was collected and analyzed. A pilot's "signature" was established by creating a transfer function relating his longitudinal stick force input to the pitch error between him and the tracking task. The results were compiled and examined for trends with pilot ratings and occurrences of PIO. The data analyzed did not reveal a parameter which would predict a PIO, but it may be useful to ensure that misleading data is not included in future attempts to do so.

Introduction

PIO can lead to severe problems. A recent example is the YF-22 PIO crash, seen on national television. PIO can occur in military or commercial aircraft and at almost any time with little warning. It is a problem that is nearly impossible to prevent, so instead a method of prediction is desired. Ground-based simulators have become an indispensable tool in the development of modern aircraft. Using simulation of tracking tasks, PIO in flight can be studied on a wide scale. The data analysis to be performed was to support the theory that simple pilot "signatures" could be derived from the tracking task. These models would then be used to identify parameters that could be used to predict an impending PIO or to explain what combinations of conditions were necessary for a PIO to exist. Power Spectral Densities of the pilot input and the tracking task and their ratios are the key element in this analysis.

Methodology

On 15 December through 18 December 1997, a series of several flight simulations was conducted using four different pilots. For each pilot, a trial was run for three different configurations and seven rate limits. The pilots would try to track a symbol that follows a specific task. The force they put on the stick, the error from where they are and where they want to be, as well as many other values were recorded onto a database. The database was altered so that a frequency data analyzing program, FREDA, could be run on it. FREDA gave a magnitude, phase, and power spectral density (PSD) for each of several frequencies around the range of interest. Graphs of the pilot's power spectral density were created to see at which frequency each pilot was using the most power, which frequency the pilot's power began to roll off, what was the highest frequency the pilot still had regular inputs, and the maximum amplitude of the PSD. In

addition to those parameters, performance parameters describing how well a pilot tracked his task were calculated. These included the root mean square (RMS) of the pitch error and the percentage of time during the run that the pitch error was within Level 1 and Level 2 acceptability. These parameters were found for every trial and compiled into categories of rate limit and configuration to search for trends.

After FREDA was run, the magnitude and phase values for the corresponding frequencies were entered into a program called "figfit." Figfit attempted to find a lower-order equivalent system for the transfer function described by FREDA. Several different methods were attempted to minimize the cost of the low-order system. The goal of this was to have a simple mathematical model for the relationship of a pilot's stick force to the pitch error, without having it become too inaccurate of a model.

Results

The results from the first portion of this investigation showed some signs of having trends. There was a very strong correlation between the RMS of pitch error and the pilots' Cooper-Harper rating. The error should increase as the rating gets worse (higher), and that is the trend that can be seen in the plots [See Figures 1,2]. This gives us confidence in the data and the pilot's ability to rate the aircraft. Another slight trend that can be observed from the graphs is the correlation between PIO rating and maximum frequency. It seems that as a pilot's PIO rating increases (e.g., as the rating gets worse), the maximum frequency declines [See Figures 3,4]. This can be interpreted to mean that as a pilot feels a plane tending to oscillate more and more, he slows down his input to a lower frequency. This is an interesting observation on how pilots react to PIO tendencies during flight. Another trend that is quite difficult to observe but still present in the data is the correlation between rate limit and the RMS of pitch error. A rate limit prevents the plane's control surfaces from pitching up or down at more than a certain angular velocity, thus putting a restraint on the pilot's control over the airplane. As we would expect, the error slightly increases as the rate limit becomes smaller and hence more significant [See Figures 5,6]. This makes for a good quality check on the data and confirms our concept of the effects of a rate limit.

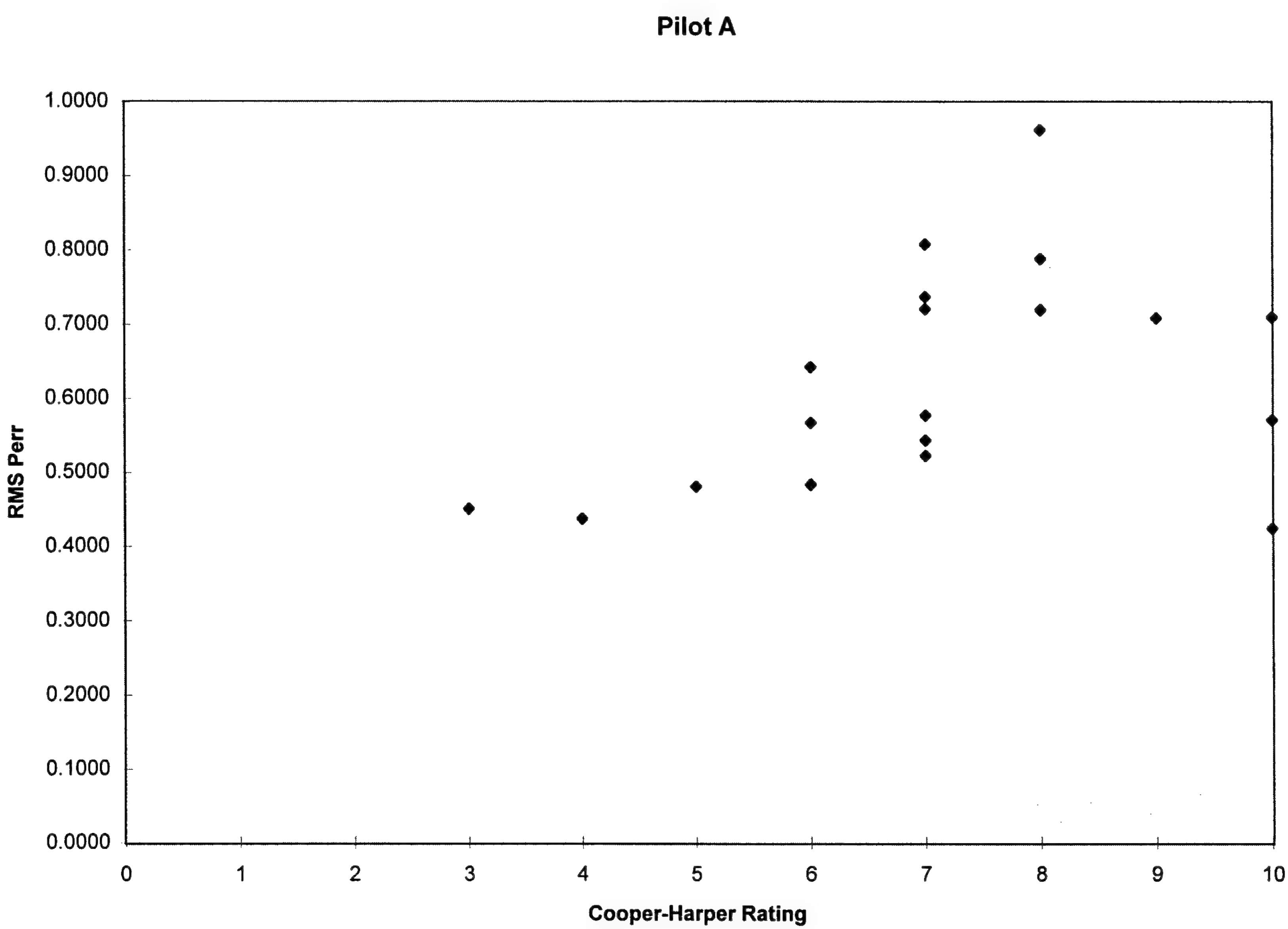
The overall results of this experiment were not as favorable as what was expected. Due to some inconsistencies in pilot performance, some of the data should not be considered valid. For example, on the worst possible configuration and rate limit, the results were not as bad as what was expected because the pilots have "backed out" of the task. They find their airplane to not have the ability to complete the given task, so they stop trying and just make sure they do not lose control of the airplane. Some of the results that were found can be used to determine which trials are not valid. For example, Pilot A has a very low maximum frequency on a trial that was assessed to have the lowest PIO rating [See Figure 3]. This point deviates from the trend so much that we can tell it is not a valid point. Most likely this is because he backed out of the task to the point that he failed to notice any PIO.

The second portion of this investigation was not as successful due to an amount of randomness that is inherent in simulated flight and also the idea of "backing out" of the task which was previously explained. Consequentially, all attempts to find a simple mathematical model of the pilot's action have failed. When figfit was made to search for a first-order over first-order fit, only 23 out of 79 trials (29%) succeeded in finding an equation with acceptable cost. When a second-order over second-order was attempted, that number was increased to 37 acceptable fits (47%). Even when the algorithm was extended to fifth-order over fifth-order equations, there were several trials that did not produce a solution with acceptable cost. This tells us that some of the simulations cannot be simplified using the means described here.

Conclusion

The results show that for some pilots, the trends of PIO occurrence correlate well with performance and roll-off frequency. Generally speaking, however, the data analyzed did not uncover a parameter or method which predicts PIO. The process does allow quick evaluation of the data quality in terms of pilot task performance and may be useful to assure that misleading data is not included in future efforts to understand this phenomenon.

Figure 1



Pilot A
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
RMS Perr
0
1
2
3
4
5
6
7
8
9
10
Cooper-Harper Rating

Figure 2

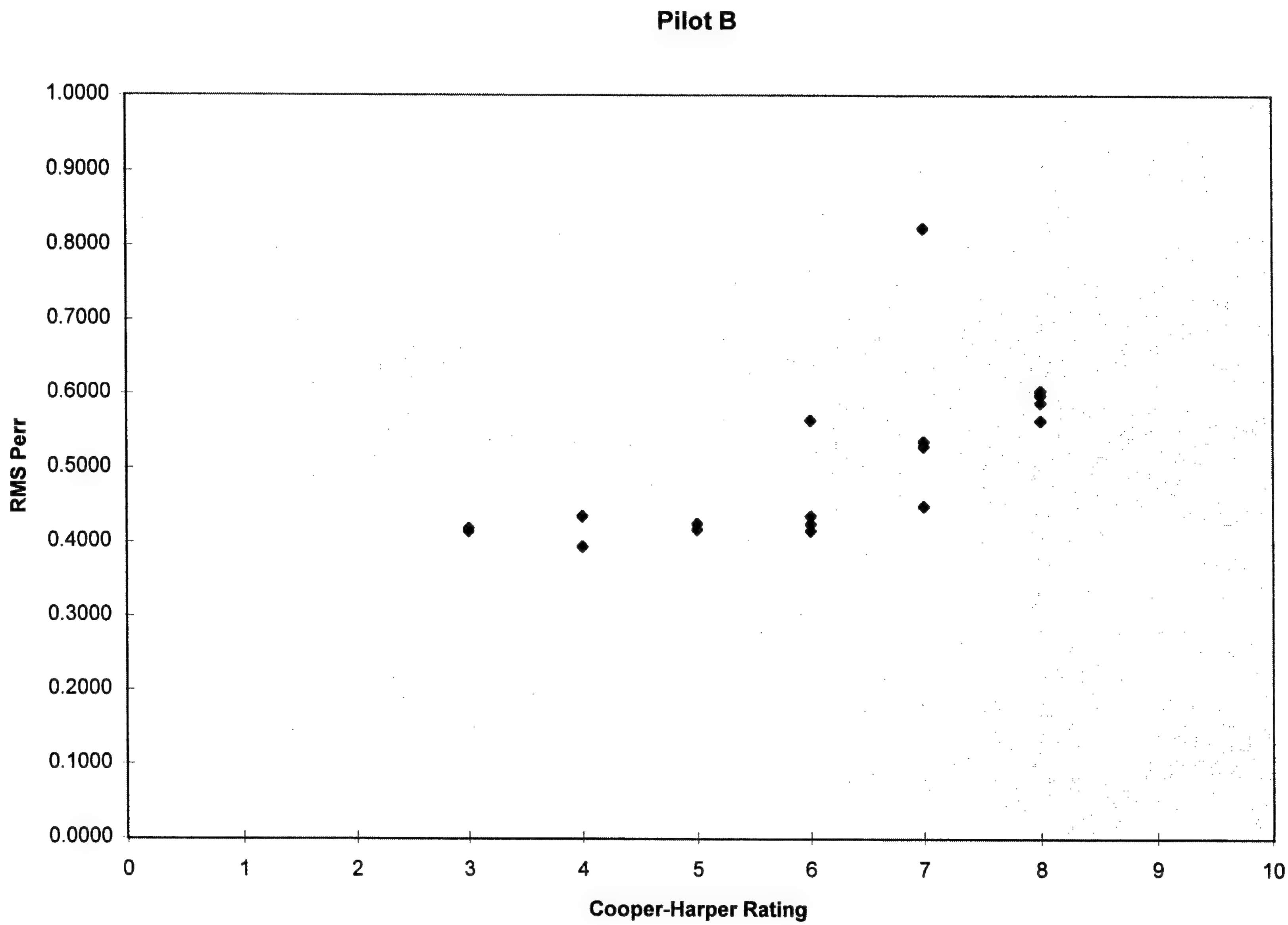

Pilot B
RMS Perr
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0
1
2
3
4
5
6
7
8
9
10
Cooper-Harper Rating

Figure 3

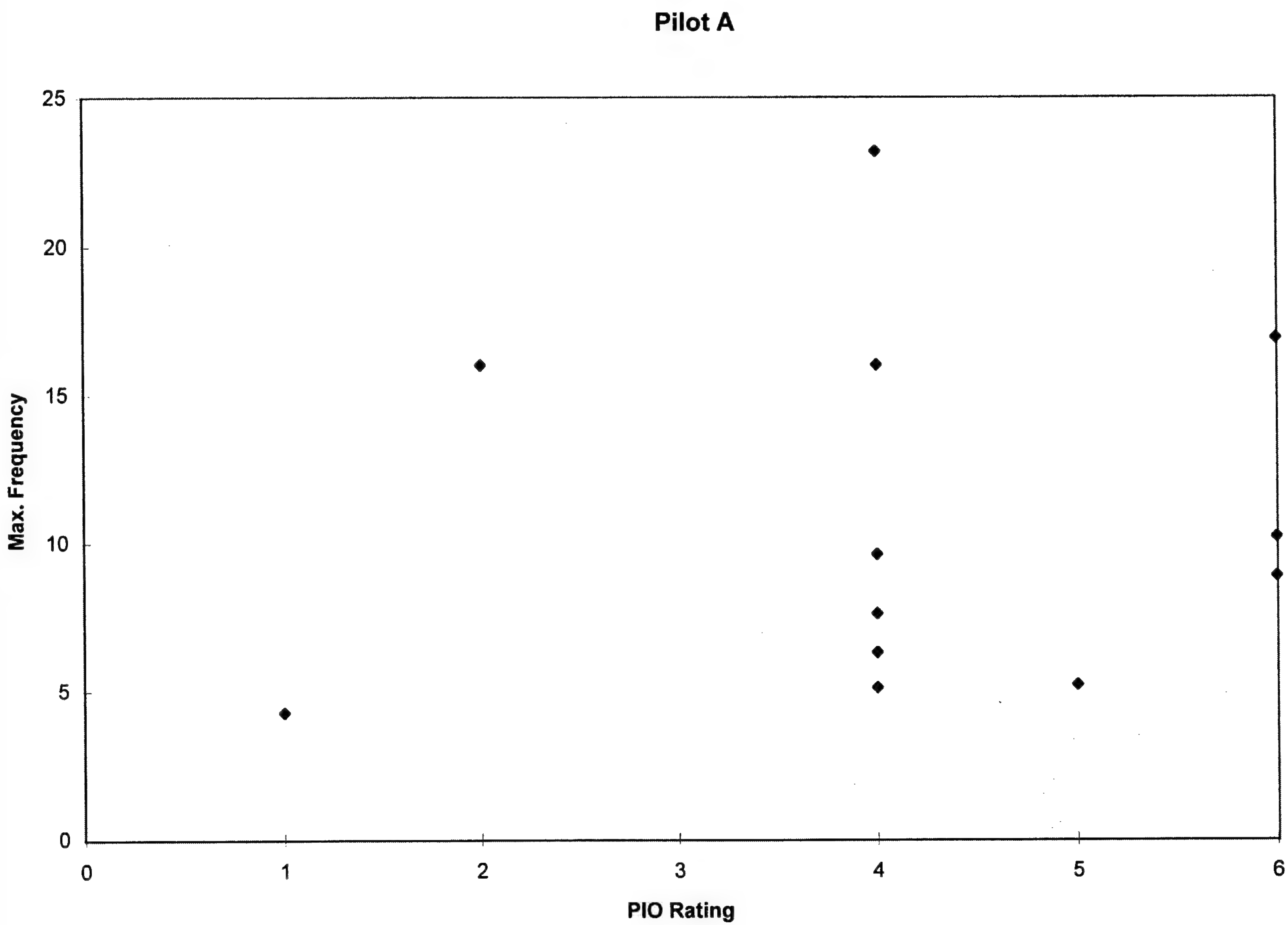


Figure 4

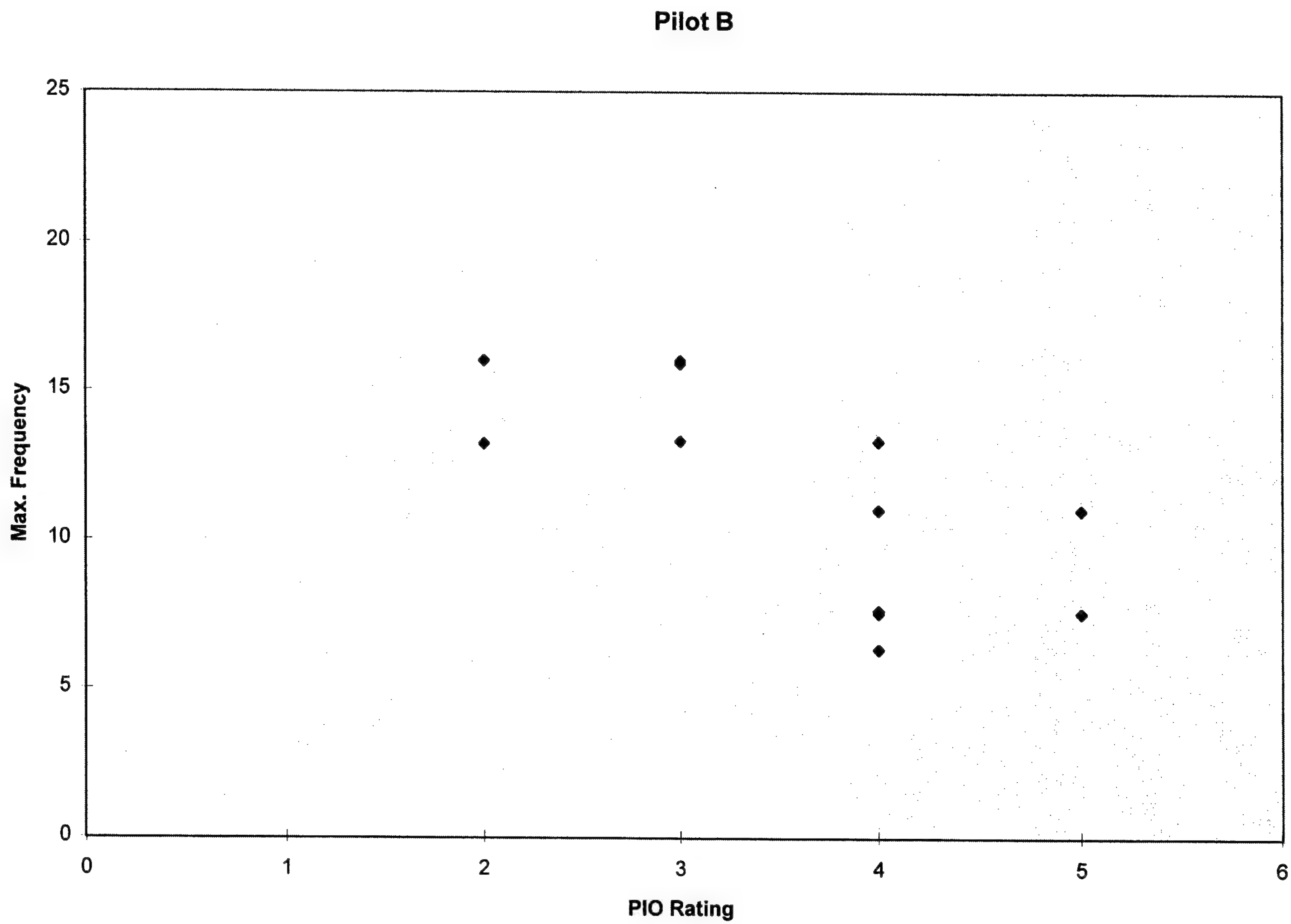


Figure 5

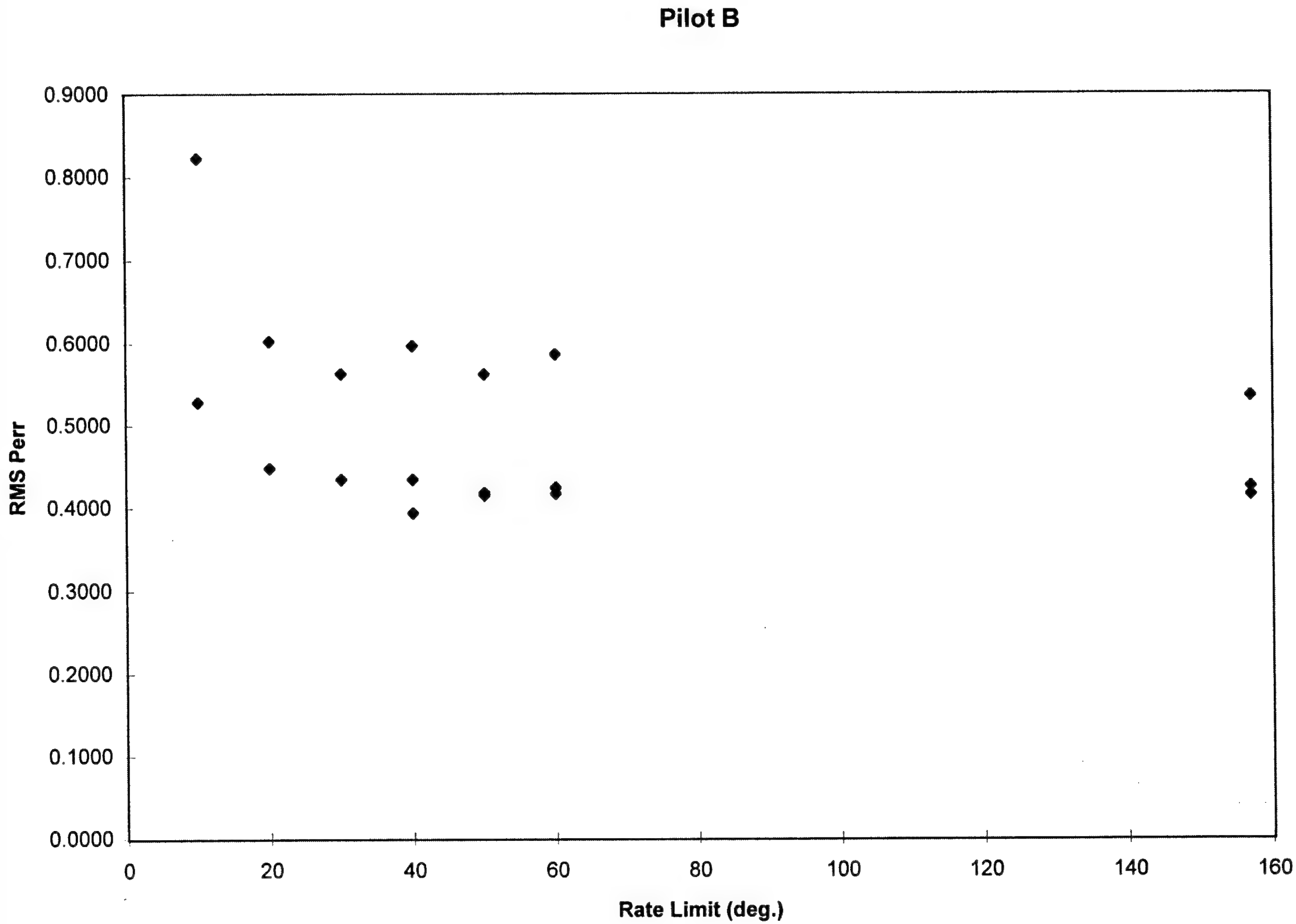
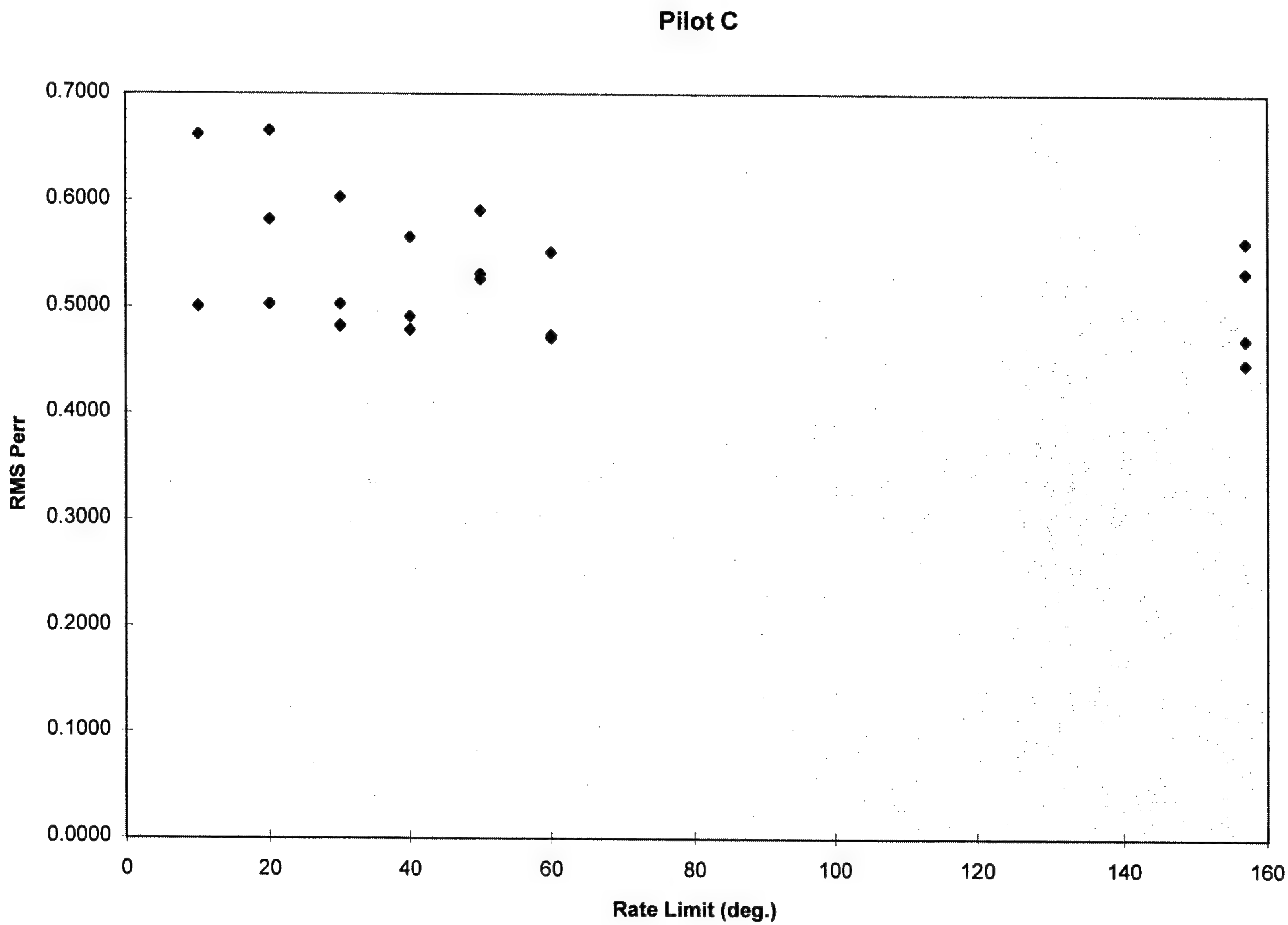

Pilot B
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
RMS Perr
0
20
40
60
80
100
120
140
160
Rate Limit (deg.)

Figure 6


Pilot C
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
RMS Perr
0
20
40
60
80
100
120
140
160
Rate Limit (deg.)

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1. Kish, Leggett, Nguyen, Cord, and Slutz, "Concepts For Detecting Pilot-Induced Oscillation Using Manned Simulation", AIAA Paper, 1996.

2. Nguyen, Ba T. and Thomas J. Cord, "Concepts For Detecting Pilot-Induced Oscillation Using Manned Simulation", AIAA Paper, 1997.

INFRARED CHARACTERIZATION OF PHOTOVOLTAIC SEMICONDUCTIVE JUNCTION DEVICES

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INFRARED CHARACTERIZATION OF PHOTOVOLTAIC SEMICONDUCTIVE JUNCTION DEVICES

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Abstract

The purpose of this project was to study the electrical properties in response to an IR signal of several different bilayer semiconductive junctions, primarily heterojunctions between indium-tin-oxide and nanoparticulate silicon embedded in a polymer matrix. This was done using a black-body source producing an IR signal. None of the devices except for the amorphous silicon showed any sensitivity to the infrared spectrum. The lack of IR sensitivity is indicative of poor IR transmittance for the clear material attached to the ITO, and the need for an inherently conductive polymer matrix in lieu of the insulating one used in these experiments.

INFRARED CHARACTERIZATION OF PHOTOVOLTAIC SEMICONDUCTIVE JUNCTION DEVICES

Alex R.Lippert

Discussion of problem/ Introduction:

Photocells active in the IR spectrum are of use in the development of weapons in that they can be used as sensors on certain weapons, especially air-to-air missiles. If the photocell experiences a change in voltage, current, or photoconductivity due to the presence of an IR source, say a jet engine, or even the jet itself, then it can signal the missile to proceed in the proper direction, or when to explode, or some other chosen command.{2} It is for this reason that we wish to characterize the electrical response across the IR spectrum of a variety of bilayer semiconductive junction devices.

Methodology:

A Mattson certified Nicolet model 851106 IR spectrometer was used to obtain IR data on the materials that were to be tested. This was used to obtain the IR spectrum from 4000-400 wave numbers(2.5-25 micron

wavelength) of pyrex, pyrex with a conductive indium-tin-oxide layer, mylar, mylar with a thin ITO layer, and mylar with a thick ITO layer.

Before the junction devices were characterized in the IR range, they were tested with a voltmeter to deterine their sensitivity to visible light.

An IR black-body source was placed on a table and lined up with an optical bench. A chopper and the photocell were placed on the optical bench and were able to be moved to vary the distance between the black-body and the photocell. A chopper was used to fluctuate the IR signal so as to provide a zero reference level.

In order to characterize the photocells over a particular wavelength, the temperature at which the spectral radiant emittance peaked over a given wavelength had to be found. This was done by putting Planck's law for spectral emission into a BASIC program that would then find the temperature range for a given wavelength band.

To test for an electrical response in the form of voltage, the photocell was connected to an oscilloscope and chopped to produce an AC signal. Any changes were noted as

the device was exposed to the IR radiation. The devices were also tested with a voltmeter, which was useful when a chopper was not available.

Several different devices were tested during the course of the experiments. The first devices were actually commercially-made silicon junctions(one made of amorphous Silicon and one made of crystalline Silicon). These devices were used as a reference to compare the quality of the other junctions. The rest of the devices were bilayer heterojunctions made of n^+ ITO coated Pyrex glass joined with a layer of an epoxy polymer containing 70% Silicon nanoparticles and pasted on an aluminum backing. In the first three junctions the ITO was bonded to non-conductive Pyrex glass which would serve to give support to the junction while still transmitting light. In junctions 1 and 2 the silicon was etched into the epoxy, while in junction 3, a ball-milling technique was used. The Si-epoxy matrix in junctions 2 and 3 consisted of 50% p-type doped nanoparticles and 50% n-type doped nanoparticles, while junction 1 was 100% p-type doped nanoparticles. These first three devices were richly doped at impurity concentrations

between 10^{19} and 10^{20} per cm^{-3}, corresponding to a resistivity between 10^{-3} and 10^{-2} Ω-cm.

The fourth device was also made of ITO and Si in an epoxy matrix, only this time the ITO was bonded to mylar (a clear plastic that was hoped to transmit infrared in the 8-12 micron range of the IR spectrum) and the epoxy was pasted to a copper backing. This is ideal for characterizing the heterojunctions in this range. The silicon nanoparticles in this device were lightly doped at impurity concentrations between 10^{15} and 10^{16} cm^{-3} corresponding to a resistivity between 1 and 10 Ω-cm.{3} A fifth device was also made in the same manner, but it tore apart due to stress put on it from gator clips.

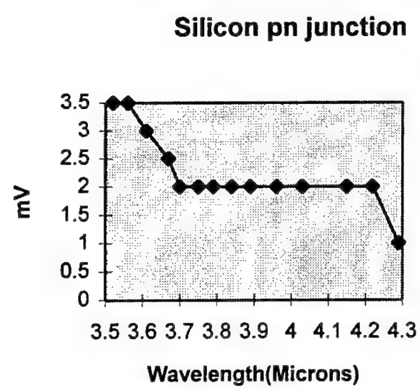
The last two devices were, again, made from mylar ITO and the nanoparticulate silicon-epoxy, only this time two pieces of Plexiglas, placed on either side of the junction, were used to provide support for the junction. In all other respects, these junctions mirrored the original mylar ITO junction.

Theoretical discussion:

A problem with devices such as these is that the hole carriers generated from photons which excite the n-type silicon are too quickly negated by the electrons in the n-type silicon, disallowing the charge to move across the material. This is the reason why nanoparticles of doped silicon held in a polymer matrix were used. With this method, the majority of the nanoparticles used are n-type, providing the necessary drift for the junction; but at the same time, a portion of the nanoparticles could be doped (p-type providing "safe havens" for the holes as they drift across the electron filled material) while still maintaining an n-type character for the material. This increases the average diffusion length of a hole and hence makes it significantly more likely that the hole will reach the other side of the junction.

Results:

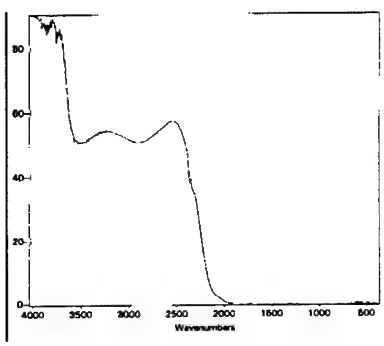
The two commercial Silicon detectors showed the expected voltages in response to optical light. The amorphous silicon showed .2 V, while the crystalline silicon showed .3 V. Although the crystalline silicon showed a higher signal in optical light, it was not sensitive to IR. The amorphous silicon was slightly sensitive in the 3-4 micron range as indicated by the chart below:



Of the other devices, only two showed any sensitivity in the optical range. One was a junction supported with the Plexiglas and the other was a silicon-epoxy/ITO/mylar junction that was not supported by Plexiglas. Unfortunately, none of the junctions showed sensitivity in the IR range.

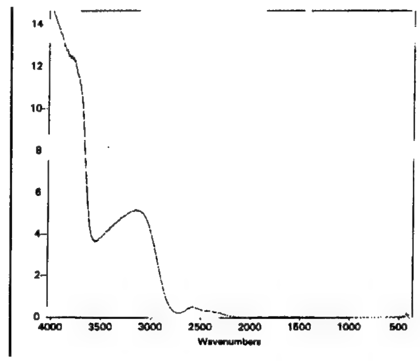
Conclusions:

An analysis of the infrared absorption spectra of the transmitting materials(Pyrex ITO and mylar ITO) can help explain why the junctions did not show sensitivity in the desired regions.



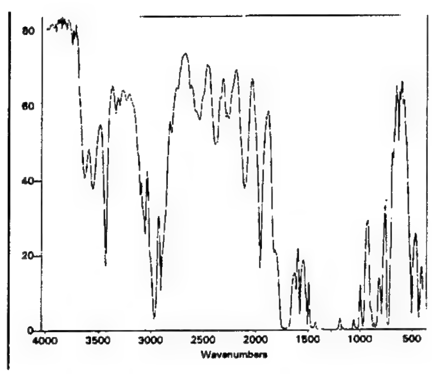
Pyrex

Using the Nicolet model 851106 spectrometer, the IR transmission of an ordinary pyrex slide is shown to be high (almost 100%) in the 4000-3500 wave number range(2.5-2.85 micron wavelength). But the IR transmission takes successive dips and approaches zero after 2000 wave numbers(approximately 5 micron wavelength).



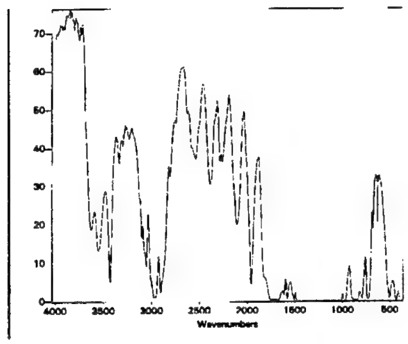
Pyrex ITO

The ITO coating drastically reduces the transmission of the pyrex reducing it to approximately 14% at 4000 wave numbers(2.5 microns).



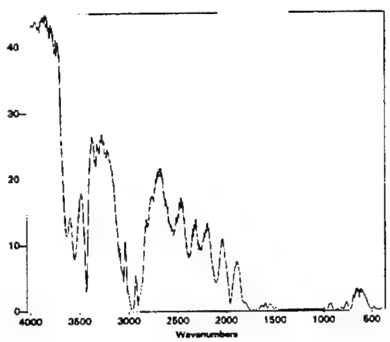
Mylar

The mylar is shown to have a high transmission over the infrared spectrum with the exception of dips at 3000 wave numbers(3.33 micron wavelength)and between 1500 and 1000 wave numbers(6.67 to 10 micron wavelength).



Mylar/"Thin Layer" ITO

A thin layer of ITO(having a resistance of 300 ohms per square) reduces the transmission by about 10%,

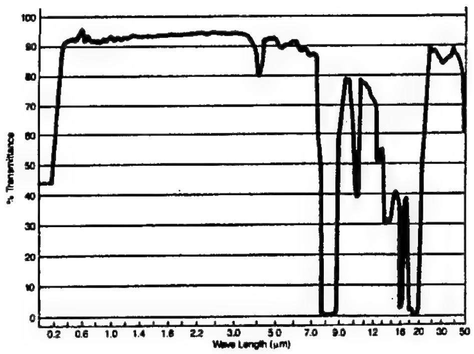


Mylar/ "Thick Layer" ITO

while a thick layer(having a resistance of 60 ohms per square) reduces the transmission a bit more drastically(between 20% and 40%).

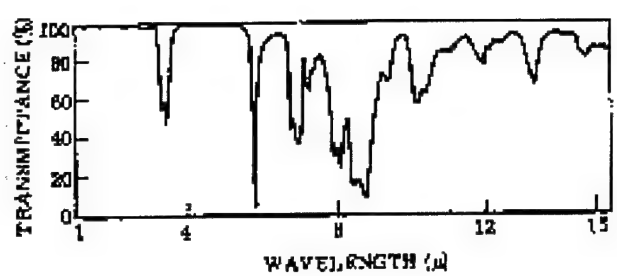
Of the junctions tested, the mylar with the thin coating of ITO demonstrated the best transmission of the 8 to 12 micron wavelength IR, providing approximately 10%

transmission. Considering the high percentage of IR transmission of Teflon between the 8 and 12 micron range(see below),



Teflon{1}

this material with an ITO coating might be an ideal replacement for mylar in detectors for sensing 8 to 12 micron wavelength IR. This is an are requiring further experimentation. Another material that would have favorable IR transmission within the range of interest would be plexiglas:



Plexiglas{4}

Given the good transmission in the desired range,

coupled with the structural reinforcement that plexiglas would give to the junction, plexiglas coated with ITO is another material for further experimentation.

Another possibility for experimentation would be to alter the nature of the Silicon-epoxy. The absence of an electronic signal could mean that the electron is not flowing through the junction. This could possibly be solved by increasing the doping levels, and therefore the conductivity, of the nanoparticles. Another solution would be to embed the nanoparticles in a inherently conductive or semiconductive polymer matrix instead of an insulating matrix.

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REDUCTIVE DEHALOGENATION OF TCE, CARBON TETRACHLORIDE, AND EDB BY HYUMIC-METAL COMPLEX

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And

Wright Laboratory

August 1998

REDUCTIVE DEHALOGENATION OF TCE, CARBON TETRACHLORIDE, AND EDB BY HUMIC-METAL COMPLEX

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Abstract

The reductive dehalogenation of TCE, CT, and EBD by humic-metal complex was studied. These halogenated hydrocarbons have contaminated both aquatic and terrestrial environments. The reduction of these compounds in nature is a very slow reaction. However, with the addition of an electron mediator the reaction is considerably sped up. In this experiment Metal-Humic Complexes were used as the electron mediator. Results indicate that Nickel-humic complex and Copper-humic complex are effective in reducing TCE, CT, and EDB.

REDUCTIVE DEHALOGENATION OF TCE, CARBON TETRACHLORIDE, AND EDB BY HUMIC-METAL COMPLEX

Lisa A. Mattingley

INTRODUCTION

Trichloroethylene (TCE), Carbon Tetrachloride and Ethylene Di-Bromide are common halogenated hydrocarbons which are extensively used in industrial and agricultural activities. Because of their usage they have contaminated aquatic and terrestrial environments (Bourg et al., 1993).

In the environment these pollutants can be degradated by a number of chemical and biological reactions, such as reductive dehalogenation. One example of reductive dehalogenation is the dechlorination of TCE. As figure 1 shows, each removal of a chlorine results in a level of degradation. The transition begins with TCE and goes to di-carbons, to vinyl chloride and finally to ethylene which is easily transformed into ethene and ethene.

Reductive dehalogenation requires the transfer of electrons from a reduced chemical to our pollutant of interest. Typically in nature this process is very slow. However, in the

presence of an electron mediator the reaction is sped up considerably. Diagram 2 illustrates this concept.

The electron mediators used were humic-metal complexes. These "humics" are naturally occurring organic compounds. They are found in all aquatic and terrestrial environments and are formed during the decomposition of plants. They also can complex dissolved metals such as Fe, Cu, Ni, etc..

The objective of these experiments was to determine whether or not humic-metal complexes can act as electron mediators in reductive dehalogenation reactions.

METHODOLOGY

Preparation of Stock Solution and Reagents. A 200mL stock solution of 250mM titanium (III) citrate in 660mM Tris buffer (pH 7.8) were prepared as described by Smith and Woods (1994). Briefly, 60mL of $TiCl_3$ were added with constant mixing to a solution of 16.0g of Tris and 29.4g sodium citrate dissolved in 80mL of argon-sparged Milli Q water. Throughout preparation the solution was sparged with argon. 20mL of 10 *M* NaOH were added and the pH adjusted to 7.8 with dropwise additions of 10 *M* NaOH. The solution was brought to a final volume of 200mL with argon-sparged Milli Q water and used within 2 hours. For systems not receiving Ti(III) citrate, a solution of Tris and sodium citrate was prepared at the same concentrations as used above, adjusted to pH 7.8 and argon sparged.

Stock solutions of the metals (10m*M*) were prepared in 100m*M* HCl. A solution of 2*M* Tris (MW 121.1) was prepared, the pH adjusted to 7.8 and argon sparged.

Aldrich Humic acid (HA) was treated extensively to remove the ash content, heavy metals and residual fulvic acids. Briefly, Aldrich HA was dissolved in NaOH followed by treatment with HF-HCl and Na saturated with Na-Chelex 100 (Bio-Rad Laboratories, Hercules, California). Excess sodium was removed by dialyzing against Milli Q water using Spectra/Por CE 1000 MWCO cellulose ester dialysis tubing (Fisher Scientific). The organic carbon content of the HS solutions was measured with a Shimadzu 5000 TOC analyzer, which is similar to the instrument designed by Sugimura and Suzuki (1988). Samples (10-40 uL) were introduced by direct aqueous injection into a platinum on alumina catalyst heated to 680'C in quartz reaction tube. The instrument was callibrated with potassium hydrogen phthalate standards.

2L of a solution of 11.1mg OC L-1 were prepared from the 2800mg OC L-1 stock solution. The pH was adjusted to 7.8 and the solution was argon sparged.

A standard solution containing TCE and heptane (internal standard) were prepared as follows; 200mg heptane and 0.998 were combined in a 2mL serum vial sealed with aluminum caps and teflon lined rubber septa.

Experimental Setup-Humic Metal Study. The reaction system consisted of 160mL serum vials crimp-sealed with teflon lined rubber septa (Supelco) containing final volumes of 100mL aqueous solution and 60mL of headspace. Each vial contained 90mL of either Milli Q water or an Aldrich HA solution containing ~11.1 mg OC L-1, to which were added 1mL of 10-2*M* metal in 0.1*M* HCl, and 0.1mL of 1*M* NaOH (vials not receiving metals were spiked with 1 mL 0.1M Hcl and 0.1mL 1M NaOH). After 24 hours, 3mL 2M Tris buffer (pH 7.8) and 6mL of 250mM titanium(III) citrate in 660mM Tris (pH 7.8) were added to each vial. Controls not receiving Ti (III) Citrate were spike with 6mL of Tris/citrate solution. The vials were sealed with aluminum crimp caps and Teflon lined rubber septa and placed on a roller drum (rotating vertically as the bottle axis remained horizontal) and kept at 20'C. All preparative work was performed in an anaerobic glove box or under continuous argon sparging. After 1 h, reactions were initiated by spiking with the given halogenated hydrocarbon (2uL of neat CT, or 5uL of neat EDB, or 2uL of TCE/heptane solution). The final solution compositions were ~10mg OC L-1 Aldrich HA, 1X 10-4 *M* metal, 100mM Tris, and 15mM titanium (III) Citrate, with a total mass of either 20.7umol CT, 58umol EDB, or 15umol TCE.

The following vials were prepared: (Where HC = either CT, EDB, or TCE)

HC
HC+Ti
HC+Ti+AHA
HC+AHA
HC+Ti+Ni
HC+Ti+Ni+AHA
HC+Ti+Co
HC+Ti+Co+AHA
HC+Ti+Cr
HC+Ti+Cr+AHA

HC+Ti+Cu
HC+Ti+Cu+AHA
HC+Ti+Fe
HC+Ti+Fe+AHA
HC+Ti+Mn
HC+Ti+Mn+AHA
HC+Ti+Mo
HC+Ti+Mo+AHA
HC+Ti+V
HC+Ti+V+AHA
HC+Ti+Zn
HC+Ti+Zn+AHA

At selected intervals headspace samples were taken from the reaction vials for analysis.

Experimental Setup-TCE Dechlorination with Ni - AHA Complex. The reaction system consisted of 160mL serum vials crimp-sealed with teflon lined rubber septa (Supelco) containing final volumes of 100mL aqueous solution and 60mL of headspace. Each vial contained 90mL of either Milli Q water or an Aldrich HA solution containing ~11.1 mg OC L-1, 3 mL 2M Tris (this amount plus the Tris present in the Ti (III) citrate solution yields a total Tris concentration of 100mL), 1mL of metal stock solution, and 0.1mL of 1M NaOH (to neutralize the HCl in the metal stock solutions); vials not receiving metals were spiked with 1 mL 0.1M Hcl and 0.1mL 1M NaOH. Vials were spiked with 2uL of TCE/heptane solution (0.9928g TCE/.200g heptane) giving final concentrations of 400ug heptane and 15umol total mass of TCE. The vials were sealed with aluminum crimp caps and Teflon lined rubber septa and placed on a roller drum (rotating vertically as the bottle axis remained horizontal) and kept at 20'C. All preparative work was performed in an anaerobic glove box or under continuous argon sparging. Reduction reactions were initiated by spiking with 6mL of the titanium (III) citrate solution (controls not receiving Ti (III) citrate were spiked with 6mL of

Tris/citrate solution). The vials were capped and returned to the roller drum. The final solution compositions were ~10mg Oc L-1, 1 X 10-4 M of each metal, 100mM Tris and 15mM titanium (III) citrate.

The following vials were prepared in duplicate:

TCE
TCE+Ti
TCE+Ti+AHA
TCE+Ti+Ni
TCE+Ti+Ni+AHA

At selected intervals 100mL headspace samples were taken from the reaction vials for analysis.

Measurement of EDB in Headspace Samples. Headspace samples (250uL) were analyzed by the method of Campbell and Burris (1996) using a Hewlett-Packard 5890 Gas Chromatograph. EDB and C2 hydrocarbon gasses were separated on 1% SP-Carboxen 1000 (60/80 mesh, 4ft.x 1/8 in ss, Supelco), packed columns respectively. Initial column sequence was the SP-1000 followed by the Carboxen 1000. Samples were injected splitless at 200'C. Carrier gas was He at 30mL min-1. Oven temperature program was 60'C for 1 min. And ramp 12'C min-1 to 198'C. The column switching valve was rotated at 1 minute runtime. Flame ionization detector temperature was 240' C.

Measurement of CT and TCE in Headspace Samples. Quantification using headspace samples was by the internal standard method (using heptane as the internal standard). Headspace samples (100uL) were analyzed using a Hewlett-Packard 5890 Series II Gas Chromatograph with a GSQ column (0.53mm by 30m) and a flame ionization detector.

Oven temperature program was 50'C for 2min., ramp 25'C min-1 to 200'C, and hold for 10 min. Flame ionization detector temperature was 280'C.

RESULTS

Figure 3 summarizes the results of the experiments. Most of the metal-complexes had no degradating effects on the three contaminants. The Nickel-humic complex and the Copper-humic complex both had reducing effects. Copper was most effective in reducing CT and EDB while Nickel was most effective in reducing TCE.

Figures 4 and 5 show the total reduction of TCE when using the Nickel-humic complex. Figure 4 shows the controls used in the experiment and that only when all four components (TCE, Titanium (III) citrate, Nickel-humic complex, and Aldrich Humic Acid) are together there is significant reduction of TCE. Figure 5 shows the development of products as a result of reducing TCE. The two biggest products are Ethene and Ethane. The top line of the graph shows the total carbon level which remained steady throughout the entire experiment.

CONCLUSION

In conclusion, Humic-Nickel and Humic-Copper complexes can act as electron mediators in reductive Dehalogenation Reactions. However, the effectiveness of these two complexes as mediators is dependent upon the halogenated hydrocarbon. TCE, CT, and EDB were completely dehalogenated by the Humic-Ni and Humic-Cu complexes.

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Smith, M.H. and S.L. Woods (1994). "Comparison of reactors for oxygen-sensitive reactions: Reductive dechlorination of chlorophenols by vitamin B12." Appl. Environ. Microbio. **60**(11): 4107-4110.

FIGURE 1

Reductive Dehalogenation

Example: TCE Dechlorinization

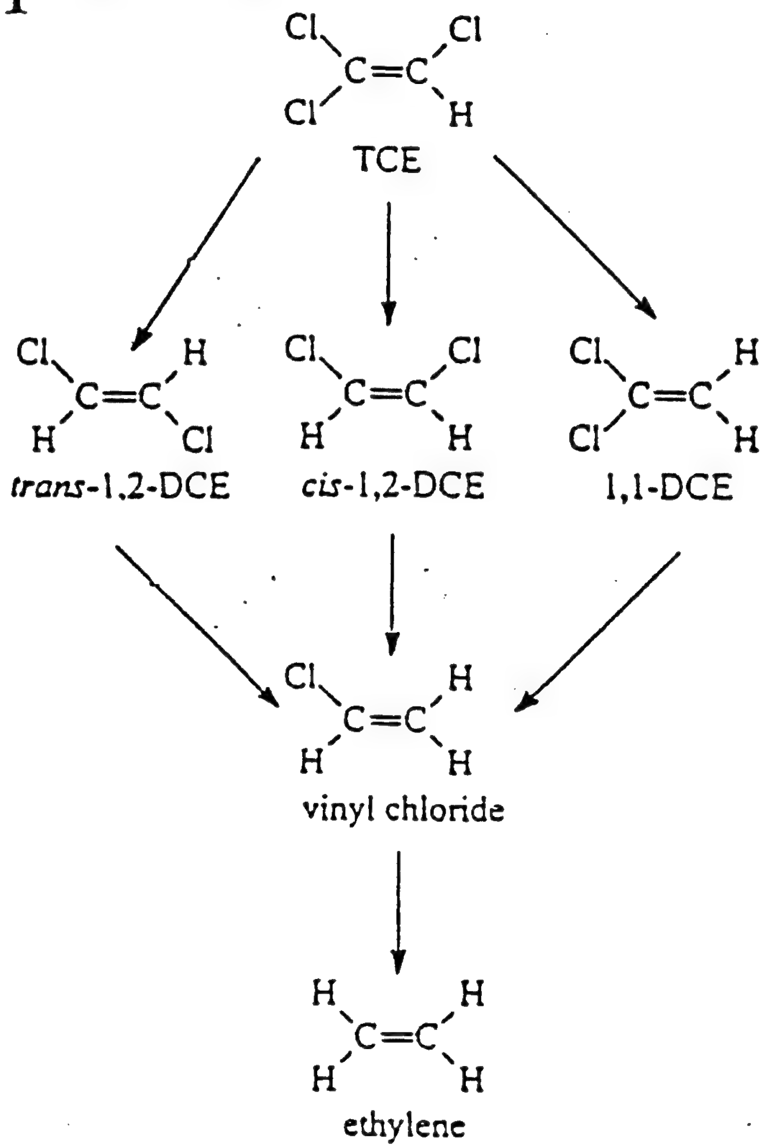
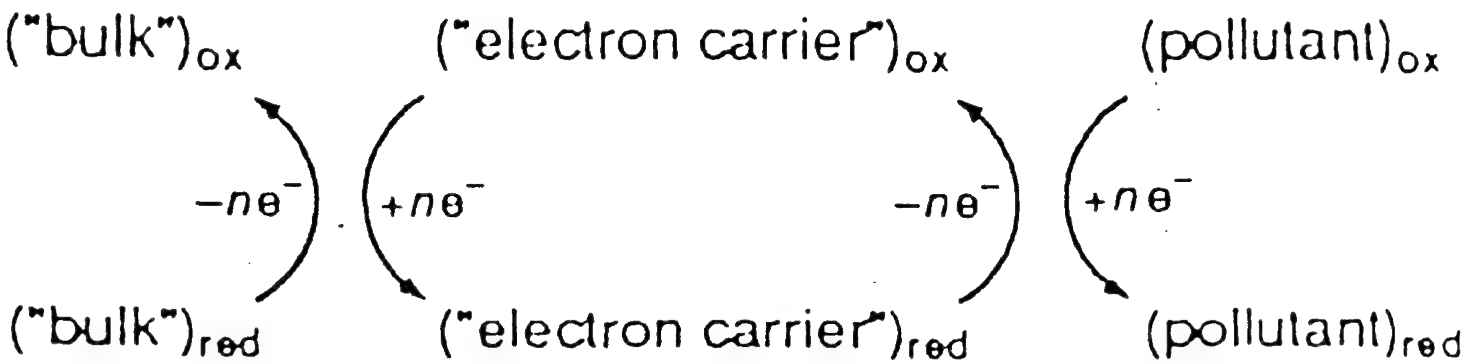


FIGURE 2

Redox Mediator Diagram



Metal Complexes Which Act as Electron Mediators:

heme (Fe)

B12 (Co)

cofactor f430 (Ni)

FIGURE 3

Results

Humic-Metal Complex	TCE	CT	EDB
Co	ne	ne	ne
Cr	ne	ne	ne
Cu	***	****	****
Fe	ne	ne	ne
Mo	ne	ne	ne
Mn	ne	ne	ne
Ni	****	*	***
V	ne	ne	ne
Zn	ne	ne	ne

ne = no effect

* = degradation

FIGURE 4

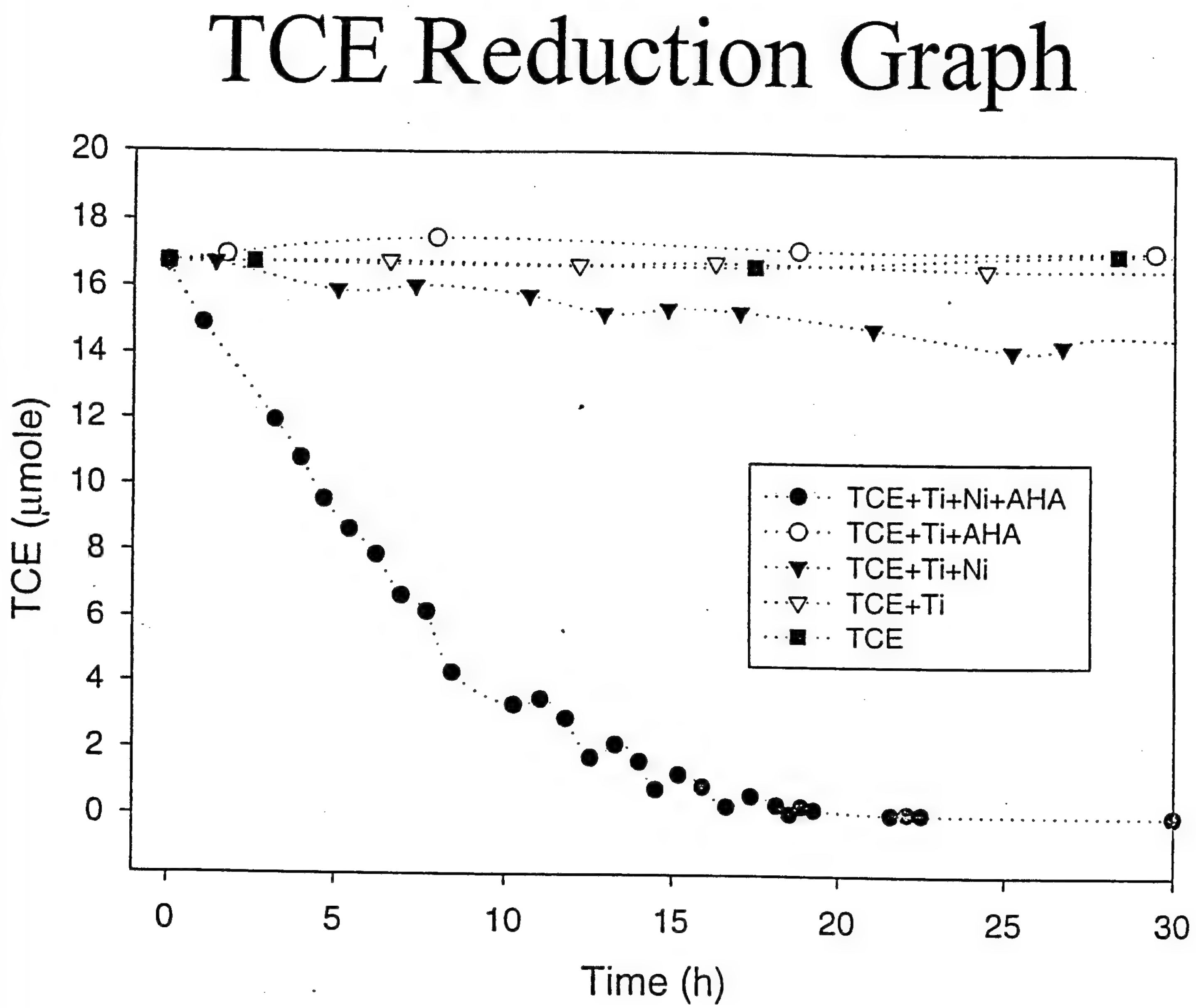
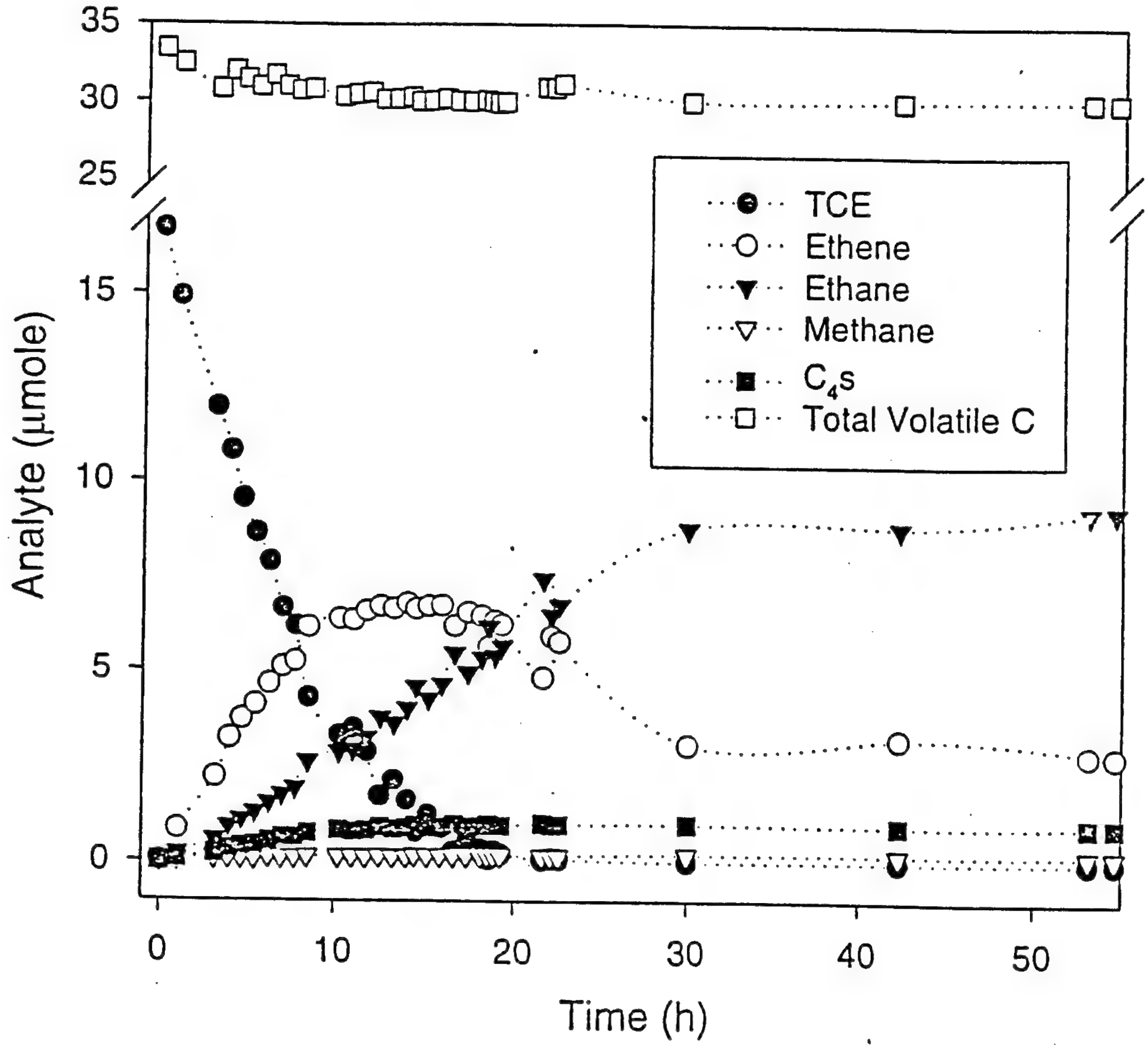

TCE Reduction Graph
TCE (µmole)
Time (h)
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
TCE+Ti+Ni+AHA
TCE+Ti+AHA
TCE+Ti+Ni
TCE+Ti
TCE

FIGURE 5

TCE Reduction: Product Formation



A STUDY OF PILOT-INDUCED OSCILLATION TENDENCIES

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Final Report for:
High School Apprenticeship Program
AFRL/Wright Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

And

Wright Laboratory

August 1998

A STUDY OF PILOT-INDUCED OSCILLATION TENDENCIES

Daniel B. McMurtry
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Abstract

Longitudinal pilot-induced oscillation (PIO) tendencies were evaluated on ground-based simulators. The results were compared to a model taken from the HAVE PIO flight test program. HAVE PIO tested a variety of aircraft dynamics on the NT-33A variable-stability landing task in both simulation and flight. Comparisons were based on Cooper-Harper ratings (CHR), PIO ratings, and pilot comments. Trends were examined and will be used to formulate concepts to make ground-based simulators a more effective tool for detecting PIO.

A STUDY OF PILOT-INDUCED OSCILLATION TENDENCIES

Daniel B. McMurtry

Introduction

Ground-bases simulators have become an indispensable tool in the development of modern aircraft. By providing piloted evaluations of aircraft flying qualities long before the aircraft is ready to fly, simulators allow designers to detect problems, redesign, and re-evaluate aircraft early in the design process. In many programs, PIOs encountered in flight test have been subsequently duplicated in the simulator. However, experience has shown that ground-based simulation has not been particularly successful at detecting PIO problems prior to flight test.

This study is part of an attempt to develop ways to modify ground based simulation methods so that PIOs if they exist, can be detected. The HAVE PIO flight test program in reference was used as the truth model. In this flight test program, 18 configurations were flown in the landing phase on the NT-33A variable-stability aircraft. All of the PIO problems were due to linear causes (excessive phase lag and low responsiveness) rather than rate limiting or mode switching. The PIO tendencies of these configurations ranged from none to severe. The wide range of tendencies was important to preclude modifications to the evaluation process which could result in false PIO predictions. My work has been to process the data from flight and ground-based simulation tests to find out more about the differences of detecting PIO between flight and ground-based simulation.

Discussion of Problem

A Pilot-Induced Oscillation is a serious problem. A PIO causes the pilot to lose control of the aircraft in a tight interaction between a pilot and aircraft. People have died as a result of this phenomenon. On the landing task it is very dangerous because it can cause the wings to wobble and possibly hit the ground crashing the plane. This is a very complicated phenomenon and the engineers try to eliminate PIO if it is at all possible.

Work Involvement

I processed the data of the Mission Simulator 1 (MS-1), the Large Amplitude Multimode Aerospace Research Simulator (LAMARS) with and without motion. These simulators were used to study PIO. The data were recorded during pilot-in the loop simulation from these simulators. The work that I got involved in were: 1) Running Frequency Domain Analysis (FREDA) software program, 2) how to use the Microsoft Excel to manipulate the data, and 3) running the Frequency Investigator and Detector of Oscillations (FIDO).

1) Power Spectral Density of Pilot Stick input: The data were stored in Microsoft Excel. I truncated the data and saved them under a different format so they can be read by Frequency Domain Analysis (FREDA) software program. FREDA is a data analysis tool in a frequency domain. It calculates the power of the pilot stick input at each frequency. The plots FREDA output showed the maximum power of the pilot stick input occurred at the PIO frequencies. This is very good information for the engineers.

2) Microsoft Excel: I used the Excel program to modify the data as the way the engineers wanted. I truncated the data around possible PIOs detected by another program. I also used Excel to plot the output of FREDA. I put the plot in logarithmic scale to show the Power Spectral Density (PSD) of the pilot stick input.

3) FIDO: I used Matlab and a Frequency Investigator and Detector of Oscillations (FIDO) program to process data from flight tests. I would go into Matlab and process the file using the FIDO HAVE LIMITS program. This produces five pages of graphs and I printed out the second, fourth, and fifth. These showed the data points of the sine curve fit to the flight test data and possible PIOs.

Results

I produced hundreds and hundreds of plots over the summer. I did not analyze any of my creations but the engineer will be analyzing them. I produced a lot of data that can be used to compare the PIO tendencies of the flight tests and the ground-based simulators. These plots will be helpful to the engineers to better understand why the ground-based simulators can not predict PIO in flight, and possibly they could use them to improve the ground-based simulation.

Conclusion

There are no solid conclusions that can be drawn from these efforts as yet. This work is premature and as this data is analyzed more thoroughly, I am confident that some changes will be made because of this work. These changes probably will take years to be put in place but it will come eventually, and it will make designs more accurate to be able to detect PIO before flight tests. After eight weeks, I did learn a lot about how engineers try to solve the real world problems. Overall, this has been a valuable learning experience in the engineering field and I feel fortunate to have been a part of such a study.

Joseph Moate's report was not available at the time of publication.

BRL-CAD MODELING OF A HARDENED FACILITY
THE CREATION OF A MEVA COMPATIBLE MODEL

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Final Report for:
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And

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August 1998

BRL-CAD MODELING OF A HARDENED FACILITY

(The Creation of a MEVA Compatible Model)

John D. Murchison
Fort Walton Beach High School

Abstract

Lethality assessment tests are to be conducted upon a test structure representative of a hardened facility. As part of the pre-test predictions phase of this project, it was necessary to create a model of the facility for use with the Modular Effectiveness/Vulnerability Architecture (MEVA), enabling a variety of possible test parameters to be simulated. The model was constructed in BRL-CAD from blue prints provided. After the model's completion it was tested for compatibility with MEVA and was found to be a compatible target file within MEVA's Target Interaction module. Additionally, a three-dimensional first person model of the facility was created for the purpose of enhancing presentational visualization of the structure and the placement of various explosive charges, instruments, and gauges.

BRL-CAD MODELING OF A HARDENED FACILITY

The Creation of a MEVA Compatible Model

John D. Murchison

Introduction

A full-scale test structure representative of a hardened command and control facility has been constructed as part of a hard target defeat program. The objective of this program is the collection of full-scale weapons effects data in an environment representative of a hardened facility. This is to include, the testing of bare and cased charges for penetrator munitions up to 2000# class, both internal and embedded detonations, and the collection of data with and without non-structural equipment. As part of the pre-test predictions phase of this project it is desired that test parameters be simulated using the Modular Effectiveness/Vulnerability Architecture MEVA. A requirement of this procedure is the construction of a target model of the facility. This model was generated using the Ballistic Research Laboratory - Computer Aided Design, package, BRL-CAD.

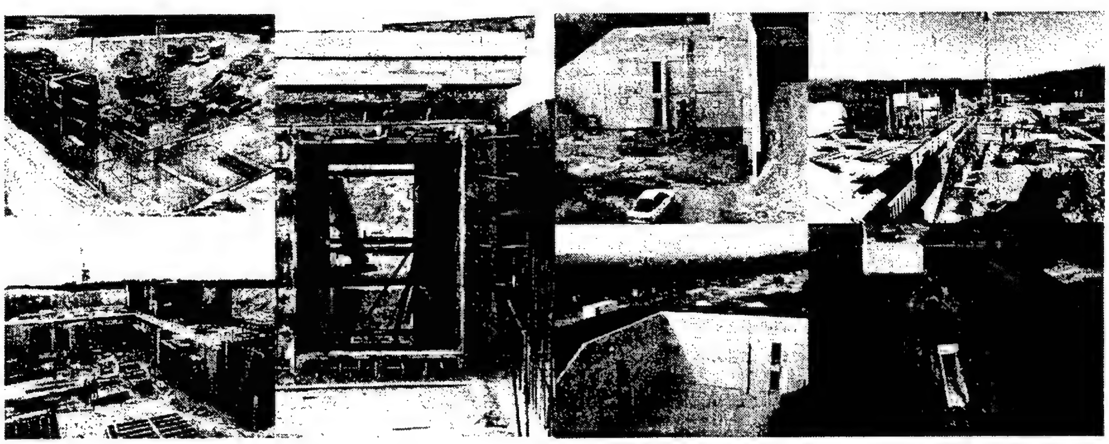
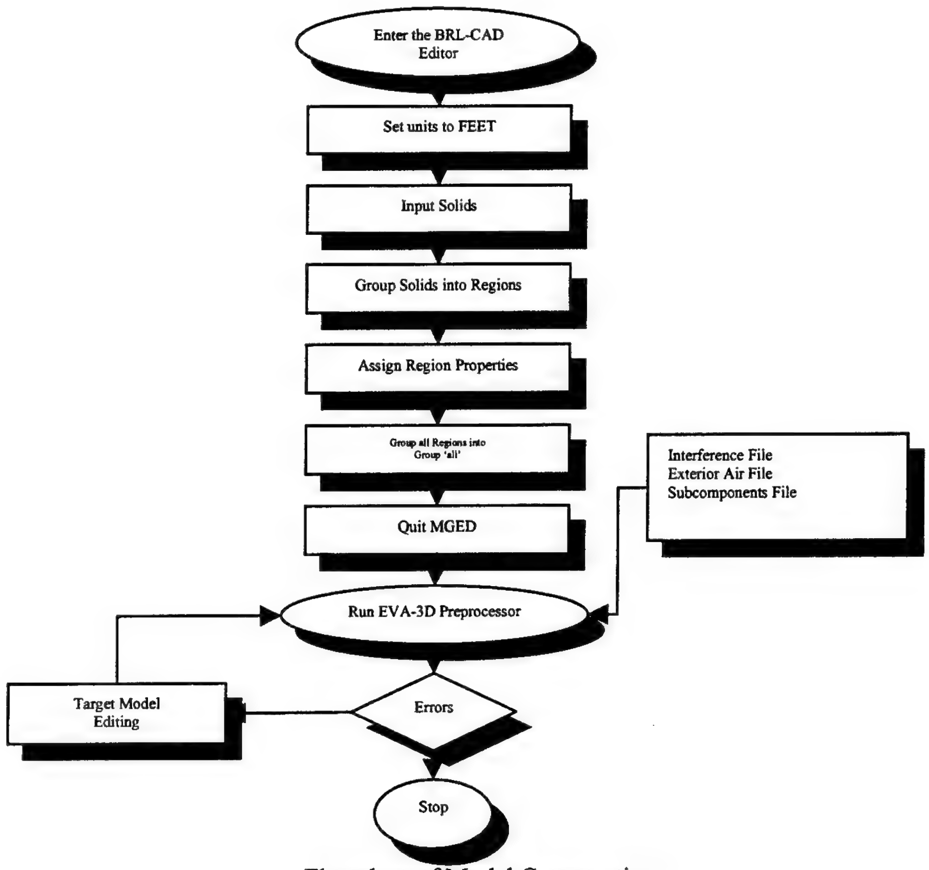


Figure 1 Pictures of Target Construction

Methodology



Flowchart of Model Construction

The Ballistic Research Laboratory - Computer Aided Design package (BRL-CAD), is a solid-modeling package which includes four major features, a solid geometric editor, a ray tracing library, two lighting models and many image-handling, data-compression, and support utilities. Most importantly it generates models compatible with the MEVA target interaction module. The first step in the construction of a target model is the determinance of one's coordinate axis. Both convenience and ease of interpretation dictate this decision. The second step is to evaluate the intelligence provided, and make appropriate decisions as to what dimensions are most likely correct. Although, in the case of modeling the facility, perfect intelligence was provided, meaning the actual blue prints were provided for the model's construction, see figure 3, conflicting dimensions were common amongst differing versions of the blue prints, forcing educated decisions to be made. The next step is to panelize the blue prints. This step is not required, but makes the process of entering solids an easier one. Panelizing is the process of splitting a wall

at its intersection with another wall, see figure 4. Panelizing a model improves the accuracy of MEVA simulations.

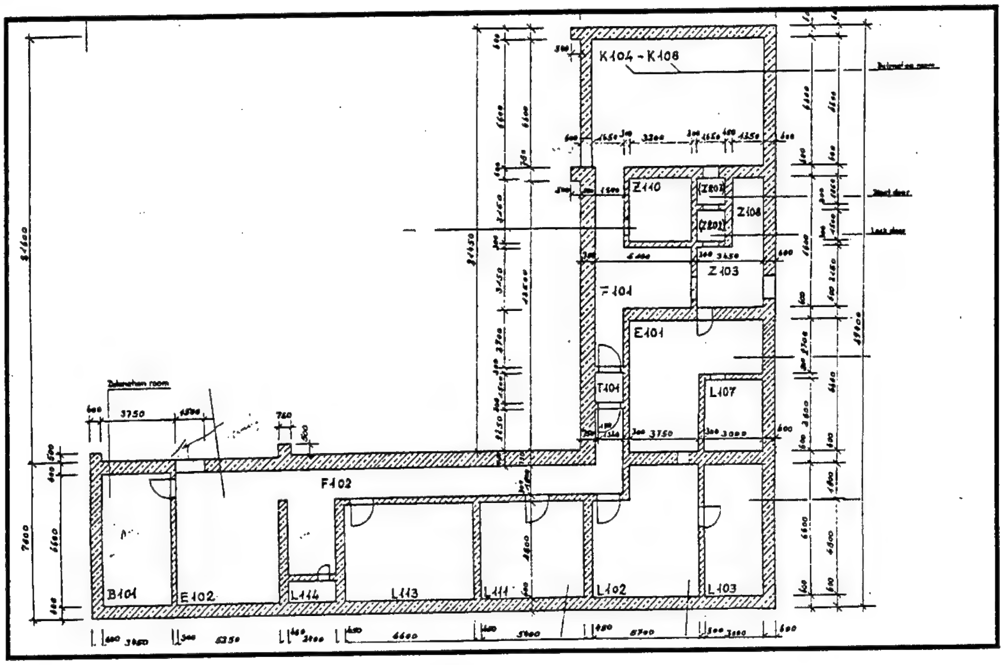


Figure 3 Sample blueprint of target facility

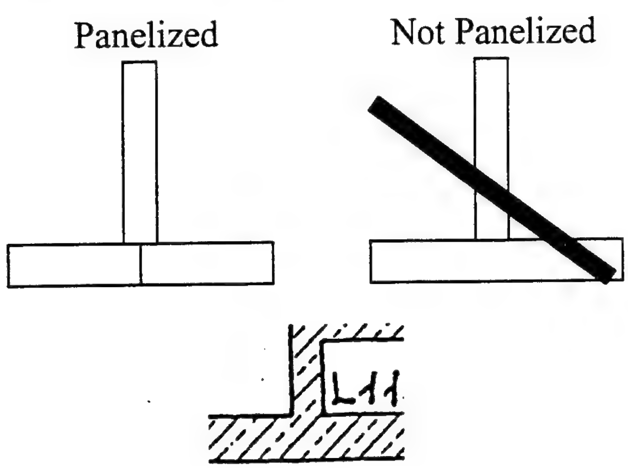


Figure 4 Example of panelization

The next step in the model's construction is the input of solids. An individual solid may comprise a wall, ceiling, floor, component, etc or portion there of. BRL-CAD provides a format for entering a variety of different solids including, rectangular parallelpipeds, boxes, arbitrary convex polyhedrons with eight vertices, arbitrary convex polyhedrons with four vertices, right circular cylinders, truncated right

cylinders, right angle wedges, spheres, general ellipsoids, and tori. The solids included within the model are rectangular parallelpipeds, arbitrary convex polyhedrons with eight vertices, and right angle wedges. The simplest manner in which to input solids comprising walls, floors, ceilings, and other similarly shaped figures was found to be the rectangular parallelpiped. Rather than depending upon the input of a x, y, and z coordinate for every vertex, it constructs the solid from a x, y, and z minimum and maximum coordinate. For convenience, when entering solids use the same units of measurement as your blue prints. Solids must then be grouped into regions. Commonly, each solid comprises a region, and as such, requires its own set of properties including what type of material it is, whether concrete, steel, soil, etc. The most efficient manner in which to group solids into regions is through the development of a text file rather than the use of the MGED BRL-CAD editor. There are several benefits in using a text file. The first is speed and ease of manipulation; the BRL-CAD MGED editor is rather cumbersome when it comes to entering a large number of commands. The second is ease of debugging and editing. It is much easier to view one's commands from within a text editor than the MGED editor. Text files are appended to a target's geometry database by using the following command from the UNIX prompt (mged target.g < file.txt). In a similar manner regions are then grouped into groups, also done more efficiently by constructing a text file. Though only a single group comprising the entire model is required for a target's import into MEVA, it is often advantageous to make subgroups, which comprise smaller sections of the model. Subgroups are also helpful in the debugging of models. Subgroups created in the construction of the model include the floor of the first floor, the walls of the first floor, the ceiling of the first floor or floor of the second floor, the walls of the second floor, and the ceiling of the second floor. If one is planning on ray tracing a model, it may be advantageous to construct a subgroup which contains only the outer walls for these will be the only regions ones that show, and this will significantly increase the speed of the ray tracing process. Ray tracing is the process of converting one's wire frame model into a solid 3d image, see figure 5. Another way in which to improve ray traces is to first group your critical components and then assign them a different color, making them stand out from your structural elements. Script files may be constructed to automate the ray tracing process, and the conversion of .pix file images to .bmp images. Additionally the use of script files is most advantageous when one wishes to construct a movie of a rotating target by incrementing the targets rotated position numerous times and repeatedly ray tracing, see appendix 1.

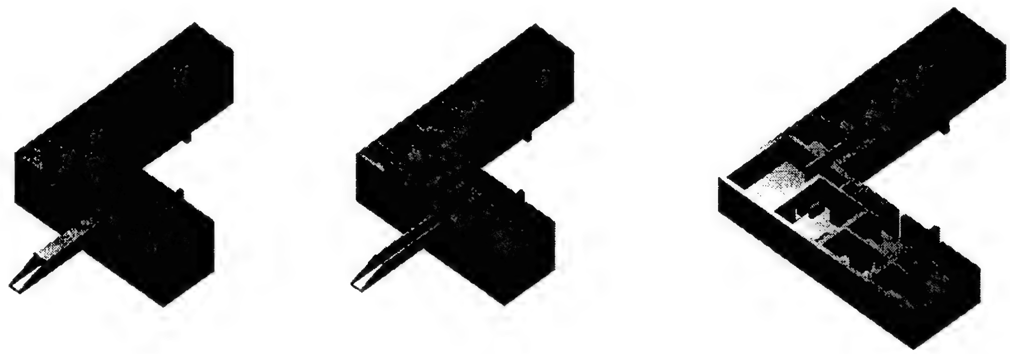


Figure 5 Ray Traces of Test Structure

Before importing a model into MEVA, the model is required to be in units of feet. Simply entering the "units ft" command within the MGED editor will do this. After completing several ray traces to check for flaws in the model's design, the model is ready for import into MEVA.

In addition to the construction of a BRL-CAD model of the facility described above, a three-dimensional first person model of the bunker was also constructed for the purpose of enhancing presentational visualization of the facility. Construction of such a model has several benefits. While a raytracing of a BRL-CAD model displays a three-dimensional rendering of a target, it does not allow the viewer to see from the vantage of actually being inside the building. A 3D first person model enables the viewer to walk throughout the facility, much as one would do if visiting the facility itself. The viewer may open doors, walk up stairs, and even turn on lights. Locations of components, gauges, and detonations may be marked or even modeled. Future improvements for such models may include the ability to take MEVA structural and component damage output and use this data to illustrate the damage inflicted, thereby allowing the viewer to gain a better idea of a simulation's results. The potential for similar models is great. In the future 3d first person models may cut down on travel expenses, as it may no longer be necessary to travel to a facility to view it in the first person.

Conclusions/Recommendations

A MEVA compatible model of the test facility was constructed using BRL-CAD. This model will enable the remainder of the pre-test predictions phase of the HTD program to be conducted, i.e. various simulations of test parameters within MEVA. Additionally it is recommended that further investigation be made into the endeavor of creating three dimensional first person target models for the purpose of enhancing presentational visualization. As previously stated, the creation of such models may enable cuts in expenditures for travel to test facilities. Editors for constructing 3-D first person models may be currently purchased commercially.

Appendix 1

rt -s1024 -A.5 -C255/255/255 -o $1.pix -a$2 -e$3 target.g (insert groups to be ray traced here)

#fb-pix -s1024 > $1.pix

pix-rle -s1024 <$1.pix >$1.rle

imconv $1.rle $1.bmp

#xv $1.bmp

s1024/ edit this number to change ray trace resolution

Command at Unix prompt/ rt1024 (filename) (azimuth) (elevation)

References

Applied Research Associates, Inc. Modular Effectiveness/Vulnerability Assessment (MEVA) in Three-Dimensions Training Course Workbook.

Applied Research Associates, Inc. Target Modeling Workbook. 4300 San Mateo Blvd. N.E., Suite A-220 Albuquerque, NM 87110

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A STUDY IN COMPUTATIONAL CHEMISTRY

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A STUDY IN COMPUTATIONAL CHEMISTRY

Nina Natarajan
Beavercreek High School

Abstract

The basics of computational chemistry were studied and a good understanding of running computational chemistry programs and the models used was gained. To perform computational chemistry calculations, molecular mechanical and quantum mechanical programs were used. Two applications of computational chemistry were examined. Three porphyrins (ethylated (EP), tetra phenyl substituted (TPP), and with both substitutions (ETPP)) were examined in order to understand the effects of substitution on the basic framework. In addition, the molecular geometry and electronic structure of Congo Red, a dye used as a biological stain, was investigated in an effort to understand the dye properties of the material for two different forms.

A STUDY OF COMPUTATIONAL CHEMISTRY

Nina Natarajan

Introduction:

With the computer technology now available, chemistry is no longer carried out solely in the laboratory. Computational Chemistry is used to assess certain properties of a molecule that would be difficult to determine experimentally. The techniques of Computational Chemistry were studied, and its basics were applied to two projects. The first project dealt with three porphyrins: EP, TTP, and ETTP in order to understand the effect of substitution on the basic framework. The second project dealt with Congo Red, a biological stain, in an effort to understand the dye properties of the material.

Methodology:

To perform computational chemistry calculations, molecular mechanics and quantum mechanical programs such as CHARMm and Mopac in Cerius2 were used. The molecules were first drawn and edited through Quanta. They were then minimized through CHARMm, and saved as a ".msf" file. They were then exported to Cerius2. In Cerius2, the Z-matrix definition was generated. A Z-matrix is listing of the atoms, their connectivity, including the bond length, bond angle, and torsional angle. An example of a Z-matrix is given in the following:

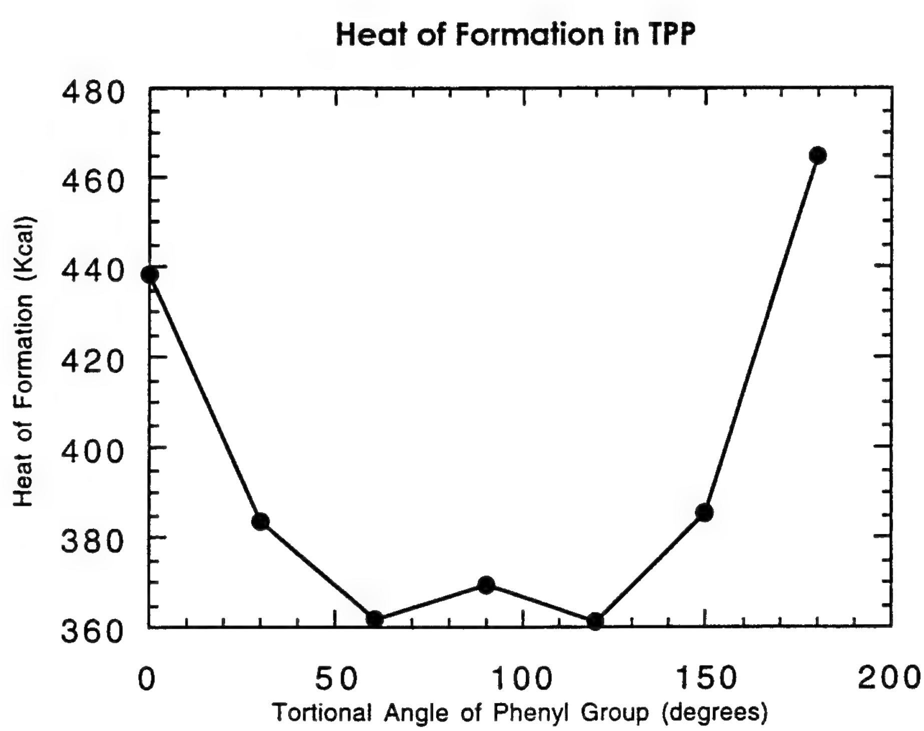
Atom #	Charge	2nd atom	Bond Length	3rd Atom	Bond Angle	4th atom	Torsional Angle
S1	2.8189	0	0.000	0	0.00	0	0.0
O2	-1.0270	1	1.440	0	0.00	0	0.0
O3	-1.0284	1	1.440	2	113.55	0	0.0
O4	-1.0268	1	1.440	2	113.57	3	132.9
C5	-0.5620	1	1.736	2	105.14	3	-113.5
C6	0.0669	5	1.416	1	122.18	2	179.9
C7	-0.1384	6	1.415	5	120.00	1	-180.0
C8	0.2532	7	1.413	6	120.03	5	0.0
N9	-0.2933	8	1.360	7	121.47	6	180.0
C10	-0.0641	9	1.400	8	118.83	7	180.0

The Z-matrix was then copied to a ".dat" file. The data was placed in the Mopac format by entering the appropriate keywords, in this case, AM1(Austin Model1)and T=99.0H (Time allowed is 99.0 hours), plus any keywords suggested by the program. Mopac93 optimization was then run to optimize the geometry and derive electronic structure parameters.

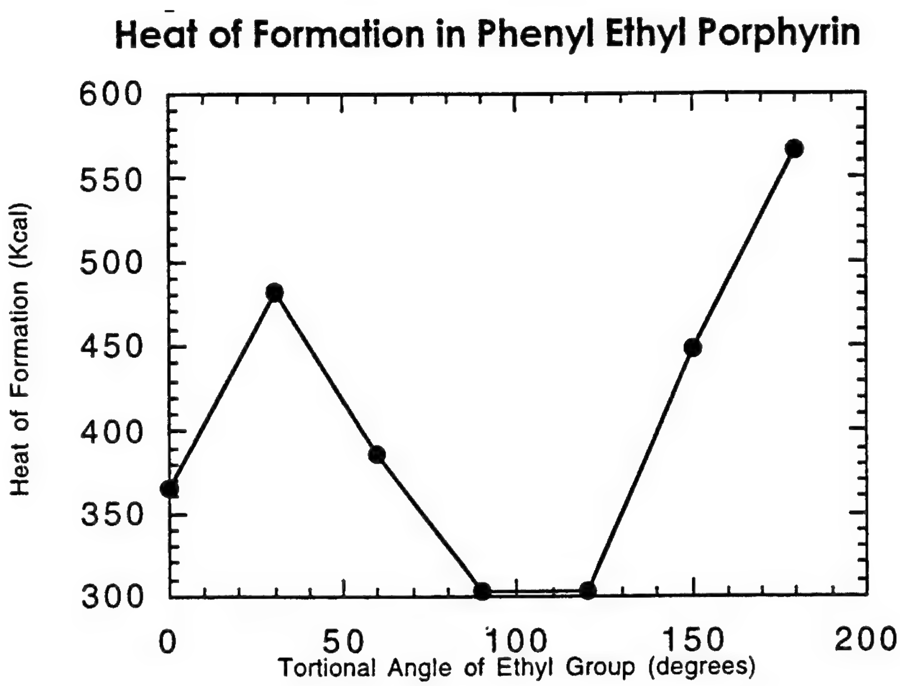
is 99.0 hours), plus any keywords suggested by the program. Mopac93 optimization was then run to optimize the geometry and derive electronic structure parameters.

Results:

These techniques were applied to the study of the Porphyrin and Congo Red molecular systems. EP, TPP, and ETPP were built as molecules in the above manner. In EPP the torsional angle of the ethyl group to the porphyrin was fixed to angles ranging from 0º to 180º, in increments of 30º. It was fixed by not optimizing the appropriate torsional angle. All other atoms were still optimized. This was similarly done to the phenyl group in TPP and for ETPP. After the calculations were completed, the respective Heats of Formation were compared and analyzed. For example, in the graph for TPP in the following, the Heat of Formation was maximal at 180º at 464.78 Kcal, clearly indicating the importance of the phenyl group effects at the meso position and the move away from co-planarity for the optimized structure.



Similarly, the effects of the additional ethyl group substitutions are indicated, as shown below.



In the Congo Red project, Congo Red was built in two different ways, one model with the sulfonate groups facing the same direction (trans), and the other model with the sulfonate groups facing opposite directions (anti). These two molecules were drawn and optimized in the previously described method. Two other molecules were imported from a ".pdb" file taken from an X- ray of the model of Congo Red. Both of these molecules (Congo Red A and Congo Red B) had the sulfonates in the *anti* formation. The difference between Congo Red A and Congo Red B was that Congo Red B was more planar than Congo Red A. These molecules were imported to Cerius2, where the Z-matrix w as created. They then were run through the Mopac93 optimization. After the molecules' preliminary run, the keyword BONDS and PRECISE were entered in order to acquire specific bond orders and to obtain more accurate results. The results are summarized below.

Calculated Congo Red Heat of Formation: 207.26 Kcal

		Charges		Bond Orders	Bond Length		Bond Angle		Dihedral Angle
S	1	2.6969	0		0.000000	0	0.000	0	-
O	2	-0.9940	1	1.447760	1.458666	0	0.000	0	-
O	3	-0.9935	1	1.446640	1.437950	2	113.157	0	-
O	4	-0.9932	1	1.135374	1.456928	2	11.233	3	(127.31)
C	5	0.5590	1	0.377901	1.760195	2	106.427	3	118.38
C	6	0.0500	5	1.136516	1.446802	1	120.219	2	174.60
C	7	-0.1383	6	1.137989	1.409595	5	119.038	1	(172.07)
C	8	0.2257	7	1.103667	1.454718	6	120.940	5	(4.41)
N	9	-0.3032	8	1.383383	1.356620	7	121.892	6	(179.61)
C	10	-0.0586	8	1.138414	1.418893	9	121.375	7	176.95
N	11	-0.1173	10	1.152238	1.403211	8	114.980	9	0.25
N	12	-0.0035	11	1.683324	1.264374	10	115.142	8	179.69
C	13	-0.0392	12	1.100517	1.429947	11	113.814	10	178.41
C	14	-0.1031	13	1.312481	1.366965	12	126.130	11	(10.59)
C	15	-0.1168	14	1.486765	1.385108	13	120.835	12	175.97
C	16	0.0021	15	1.313046	1.414418	14	120.350	13	0.49
C	17	0.0024	16	1.043287	1.502273	15	119.974	14	178.68
C	18	-0.1168	17	1.313179	1.414418	16	119.974	15	(180.00)
C	19	-0.1029	18	1.486909	1.385108	17	120.350	16	178.68
C	20	-0.0396	19	1.312386	1.366965	18	120.835	17	0.49
N	21	-0.0032	20	1.006740	1.429947	19	126.130	18	175.97
N	22	-0.1177	21	1.683033	1.264374	20	113.814	19	(10.59)
C	23	-0.0578	22	1.152556	1.403211	21	115.142	20	178.41
C	24	0.2256	23	1.137523	1.419282	22	114.948	21	(179.71)
N	25	-0.3024	24	1.385109	1.355742	23	121.411	22	(0.21)
C	26	-0.1385	24	1.103047	1.455229	25	121.918	23	177.02
C	27	0.0497	26	1.318020	1.409595	24	120.968	25	179.58
C	28	-0.5582	27	1.135108	1.447744	26	119.026	24	4.40
S	29	2.6966	28	0.377815	1.759965	27	120.176	26	172.08
O	30	-0.9938	29	1.144893	1.458715	28	106.373	27	(174.64)
O	31	-0.9933	29	1.144789	1.437950	30	113.139	28	118.36
O	32	-0.9931	29	1.135281	1.457126	30	111.273	33	127.37
C	33	-0.0506	23	1.272304	1.400818	22	123.487	24	(178.86)
C	34	-0.0472	27	1.273353	1.423811	26	117.945	28	177.85
C	35	-0.0891	34	1.492695	1.371623	27	120.677	28	(0.24)
C	36	-0.1073	35	1.310968	1.405849	34	121.008	27	(2.01)
C	37	-0.1040	26	1.515831	1.421573	24	119.261	27	(179.65)
C	38	-0.0591	20	1.468822	1.395149	21	114.598	19	(178.47)
C	39	-0.1260	17	1.354302	1.376279	16	122.130	18	(179.85)
C	40	-0.1260	16	1.354439	1.376279	15	117.896	17	(179.86)
C	41	-0.0592	13	1.302012	1.394846	12	114.649	14	178.45
C	42	-0.0503	5	1.523929	1.357622	1	119.896	6	(175.82)
C	43	-0.1042	7	1.263535	1.421573	6	119.769	8	(179.63)
C	44	-0.1071	43	1.468412	1.360100	7	120.999	6	1.29
C	45	-0.0896	44	1.310438	1.405442	43	119.525	7	0.99
C	46	-0.0471	6	1.271846	1.424574	5	123.005	7	177.75

H	47	0.2694	9	0.871632	1.090000	8	109.470	7	3.05
H	48	0.3139	9	0.850818	1.090000	8	125.273	47	(179.95)
H	49	0.2696	25	0.871520	1.090000	24	109.470	23	(180.00)
H	50	0.3141	25	0.850710	1.090000	24	125.281	49	179.93
H	51	0.2112	33	0.920382	1.090000	23	119.034	28	(179.95)
H	52	0.1146	37	0.942385	1.090000	26	119.499	27	179.98
H	53	0.1482	36	0.946007	1.090000	35	120.232	37	(180.00)
H	54	0.1572	35	0.944084	1.090000	34	119.471	36	180.00
H	55	0.2034	34	0.925559	1.090000	27	119.640	35	(179.99)
H	56	0.1463	39	0.943531	1.090000	17	119.298	38	(179.93)
H	57	0.1714	38	0.939841	1.090000	20	119.884	39	179.92
H	58	0.1447	19	0.946349	1.090000	18	119.602	20	179.79
H	59	0.1468	18	0.943652	1.090000	17	119.831	19	179.97
H	60	0.1715	41	0.939855	1.090000	13	119.874	40	179.98
H	61	0.1465	40	0.943488	1.090000	16	119.329	41	179.99
H	62	0.1468	15	0.943672	1.090000	14	119.819	16	179.96
H	63	0.1448	14	0.946347	1.090000	13	119.596	15	(179.97)
H	64	0.2110	42	0.920403	1.090000	5	119.021	10	(179.94)
H	65	0.2033	46	0.925618	1.090000	6	119.640	45	(179.97)
H	66	0.1571	45	0.944114	1.090000	44	119.492	46	180.00
H	67	0.1481	44	0.946037	1.090000	43	120.227	45	179.95
H	68	0.1146	43	0.942400	1.090000	7	119.512	44	179.99

				Bond Orders		Bond Length		Bond Angle		Dihedral Angle
S	1	2.8703	0	0.309720		0.000	0	0	0	0.0
O	2	-1.0337	1	1.147118		1.455	0	0.00	0	0.0
O	3	-1.3300	1	1.156820		1.473	2	112.74	0	0.0
O	4	-1.0374	1	1.142355		1.464	2	112.01	3	127.9
C	5	-0.5058	1	1.189806	1.430685	1.761	2	107.05	3	-116.5
C	6	0.0261	5	1.254223		1.422	1	122.75	2	-60.9
C	7	-0.1288	6	1.316177		1.401	5	119.47	1	179.6
C	8	0.2327	7	1.111982		1.465	6	120.44	5	2.4
N	9	-0.2757	8	1.353998		1.374	7	120.79	6	178.0
C	10	-0.0558	9	1.104658		1.382	8	121.75	7	179.1
N	11	-0.1189	10	1.735672		1.430	8	114.80	9	-0.1
N	12	-0.0269	11	1.080218		1.229	10	112.18	8	-173.3
C	13	-0.0379	12	1.308576		1.440	11	114.27	10	-178.6
C	14	-0.0629	13	1.472444		1.369	12	114.85	11	-173.7
C	15	-0.1292	14	1.340260		1.383	13	120.23	12	-179.6
C	16	-0.0089	15	1.042741		1.404	14	121.23	13	1.7
C	17	-0.0034	16	1.340458		1.476	15	119.56	14	175.1
C	18	-0.1255	17	1.472362		1.388	16	120.90	15	-24.9

C	19	-0.1023	18	1.308334		1.389	17	121.39	16	-176.6
C	20	-0.0416	19	1.082891		1.389	18	119.86	17	1.4
N	21	-0.0257	20	1.734882		1.424	19	125.46	18	172.9
N	22	-0.1226	21	1.102077		1.268	20	112.52	19	-4.6
C	23	-0.0539	22	1.116130		1.415	21	115.01	20	179.9
C	24	0.2325	23	1.108915		1.404	22	114.56	21	-173.7
N	25	-0.2706	24	1.364146		1.363	23	121.28	22	-1.8
C	26	-0.1265	24	1.253204		1.448	25	121.47	23	179.4
C	27	0.0191	26	1.194188		1.427	24	120.54	25	178.6
C	28	-0.4877	27	1.411344		1.418	26	118.88	24	1.7
S	29	2.8733	28	0.302163		1.769	27	121.65	26	178.9
O	30	-1.0315	29	1.154079		1.461	28	106.39	27	-178.4
O	31	-1.0375	29	1.142925		1.450	30	113.29	28	116.6
O	32	-1.0313	29	1.150936		1.468	30	111.24	33	127.4
C	33	-0.0724	23	1.354296		1.412	22	123.44	24	178.4
C	34	-0.0308	27	1.294251		1.428	26	117.57	28	-177.4
C	35	-0.1029	34	1.438509	1.367689	1.383	27	120.89	28	-3.4
C	36	-0.1109	35	1.367689		1.383	34	120.01	27	1.0
C	37	-0.0971	26	1.319350		1.413	24	120.75	27	179.9
C	38	-0.0609	20	1.308599	1.442674	1.378	21	114.64	19	176.4
C	39	-0.1300	17	1.341869		1.386	16	120.95	18	-176.8
C	40	-0.1230	16	1.342467	1.469068	1.381	15	117.87	17	-177.4
C	41	-0.1053	13	1.312440		1.384	12	124.73	14	-179.6
C	42	-0.0690	5	1.337137		1.372	1	117.86	6	-178.1
C	43	-0.0965	7	1.446292		1.400	6	120.05	8	179.0
C	44	-0.1145	43	1.364824		1.400	7	120.85	6	1.9
C	45	-0.1019	44	1.441465		1.397	43	117.44	7	-2.1
C	46	-0.0317	6	1.295627		1.408	5	122.31	7	-177.7
H	47	0.2465	9	0.898325		1.090	8	109.47	7	0.9
H	48	0.2628	9	0.893779		1.090	8	125.3	47	180.0
H	49	0.2475	25	0.897919		1.090	24	109.47	23	180.0
H	50	0.2649	25	0.892665		1.090	24	125.27	49	180.0
H	51	0.2113	33	0.919241		1.090	23	119.85	28	179.9
H	52	0.1213	37	0.947913		1.090	26	119.17	27	-179.9
H	53	0.1474	36	0.945695		1.090	35	119.49	37	-180
H	54	0.1577	35	0.943143		1.090	34	119.98	36	179.9
H	55	0.2038	34	0.923046		1.090	27	119.56	35	-180.0
H	56	0.1483	39	0.943926		1.090	17	119.42	38	-179.9
H	57	0.1680	38	0.939290		1.090	20	120.18	39	180.0
H	58	0.1449	19	0.945773		1.090	18	120.07	20	-180
H	59	0.1448	18	0.944844		1.090	17	119.32	19	180.0
H	60	0.1444	41	0.946002		1.090	13	120.41	40	180
H	61	0.1448	40	0.944772		1.090	16	119.47	41	179.9
H	62	0.1469	15	0.944280		1.090	14	119.39	16	180
H	63	0.1680	14	0.939334		1.090	13	119.9	15	180
H	64	0.2099	42	0.919514		1.090	5	118.96	10	-180.0
H	65	0.2030	46	0.923567		1.090	6	119.54	45	180.0
H	66	0.1566	45	0.943420		1.090	44	118.74	46	-180.0

H	67	0.1453	44	0.946272	1.090	43	121.29	45	-180.0
H	68	0.1201	43	0.948050	1.090	7	119.58	44	-180.0

Congo Red (molecule A) Heat of Formation: 257.25 Kcal

		Charges		Bond Orders	Bond Length		Bond Angle		Dihedral Angle
S	1	2.6557	0	0.000000	0.000	0	0.00	0	0.00
O	2	-0.9805	1	1.144546	1.455	0	0.00	0	0.00
O	3	-0.9827	1	1.142680	1.473	2	112.74	0	0.00
O	4	-0.9805	1	1.138895	1.464	2	112.01	3	127.86
C	5	-0.5473	1	0.385332	1.761	2	107.05	3	-116.50
C	6	0.026	5	1.896990	1.422	1	122.75	2	-60.86
C	7	-0.1126	6	1.290321	1.401	5	119.47	1	179.55
C	8	0.2151	7	1.078331	1.465	6	120.44	5	2.35
N	9	-0.317	8	1.343924	1.374	7	120.79	6	177.95
C	10	-0.095	8	1.206793	1.382	9	121.75	7	179.10
N	11	-0.0959	10	1.061097	1.430	8	114.80	9	-0.05
N	12	-0.0084	11	1.802298	1.230	10	112.18	8	-173.27
C	13	-0.053	12	1.039355	1.440	11	114.27	10	-178.57
C	14	-0.0696	13	1.332470	1.369	12	114.85	11	-173.65
C	15	-0.1238	14	1.469760	1.383	13	120.23	12	-179.57
C	16	-0.0149	15	1.333444	1.404	14	121.23	13	1.68
C	17	0.0064	16	1.024369	1.476	15	119.56	14	175.06
C	18	-0.1232	17	1.335221	1.388	16	120.90	15	-24.93
C	19	-0.0947	18	1.479770	1.389	17	121.39	16	-176.60
C	20	-0.0629	19	1.302832	1.389	18	119.86	17	1.41
N	21	0.0125	20	1.084631	1.424	19	125.46	18	172.88
N	22	-0.1254	21	1.721534	1.268	20	112.56	19	-4.62
C	23	-0.0646	22	1.115131	1.415	21	115.01	20	179.92
C	24	0.2247	23	1.151602	1.404	22	114.56	21	-173.69
N	25	-0.3009	24	1.374587	1.363	23	121.83	22	-1.84
C	26	-0.136	24	1.104950	1.448	25	121.47	23	179.36
C	27	0.0349	26	1.280319	1.427	24	120.54	25	178.57
C	28	-0.5421	27	1.182533	1.418	26	118.88	24	1.70
S	29	2.66	28	0.376855	1.769	27	121.65	26	178.90
O	30	-0.983	29	1.149353	1.461	28	106.39	27	-178.41
O	31	-0.9827	29	1.444030	1.450	30	113.29	28	116.61
O	32	-0.9777	29	1.140192	1.468	30	111.24	33	127.38
C	33	-0.0387	23	1.315664	1.412	22	123.44	24	178.44
C	34	-0.0237	27	1.275703	1.428	26	117.57	28	-177.43
C	35	-0.0933	34	1.457620	1.383	27	120.89	28	-3.44
C	36	-0.1027	35	1.346112	1.383	34	120.01	27	1.00
C	37	-0.0925	26	1.477773	1.413	24	120.75	27	179.94
C	38	-0.057	20	1.343185	1.378	21	114.64	19	176.40
C	39	-0.1296	17	1.377501	1.339	16	120.95	18	-176.84
C	40	-0.1162	16	1.387553	1.381	15	117.87	17	-177.44
C	41	-0.101	13	1.357082	1.384	12	124.73	14	-179.56
C	42	-0.0268	5	1.440771	1.372	1	117.86	6	-178.13
C	43	-0.1082	7	1.329290	1.400	6	120.05	8	178.95

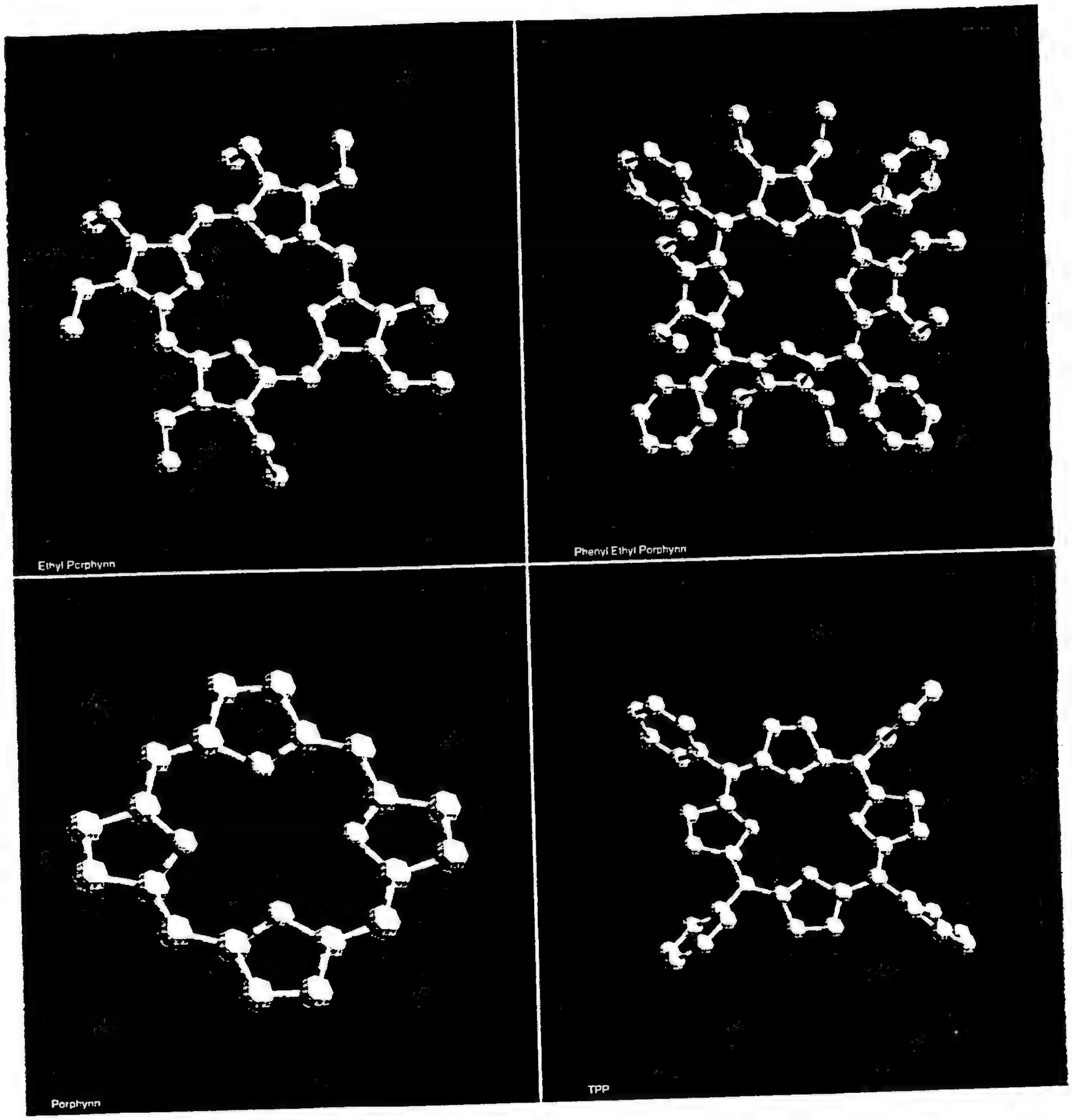
C	44	-0.087	43	1.438085	1.400	7	120.85	6	1.89
C	45	-0.1137	44	1.350339	1.397	43	117.44	7	-2.12
C	46	-0.0249	6	1.264523	1.408	5	122.31	7	-177.67
H	47	0.2641	9	0.873917	1.090	8	109.47	7	0.90
H	48	0.312	9	0.851415	1.090	8	125.30	47	179.98
H	49	0.2678	25	0.873741	1.090	24	109.47	23	180.00
H	50	0.3163	25	0.849195	1.090	24	125.27	49	179.99
H	51	0.2189	33	0.917052	1.090	23	119.85	28	179.94
H	52	0.116	37	0.943267	1.090	26	119.17	27	-179.90
H	53	0.147	36	0.946523	1.090	35	119.49	37	-179.97
H	54	0.1613	35	0.942957	1.090	34	119.98	36	179.95
H	55	0.2034	34	0.926148	1.090	27	119.56	35	-179.99
H	56	0.1474	39	0.945401	1.090	17	119.42	38	-179.95
H	57	0.1703	38	0.939764	1.090	20	120.18	39	179.99
H	58	0.1431	19	0.946612	1.090	18	120.07	20	-179.98
H	59	0.1451	18	0.945267	1.090	17	119.32	19	179.98
H	60	0.1472	41	0.945727	1.090	13	120.41	40	179.98
H	61	0.1428	40	0.946040	1.090	16	119.47	41	179.94
H	62	0.145	15	0.945696	1.090	14	119.39	16	179.97
H	63	0.1691	14	0.939981	1.090	13	119.90	15	-179.98
H	64	0.2142	42	0.919145	1.090	5	118.96	10	-180.00
H	65	0.2014	46	0.926632	1.090	6	119.54	45	180.00
H	66	0.1542	45	0.945120	1.090	44	118.74	46	-179.99
H	67	0.1535	44	0.944630	1.090	43	121.29	45	-179.98
H	68	0.1177	43	0.941825	1.090	7	119.58	44	-179.98

Congo Red (molecule B) Heat of Formation: 250.59

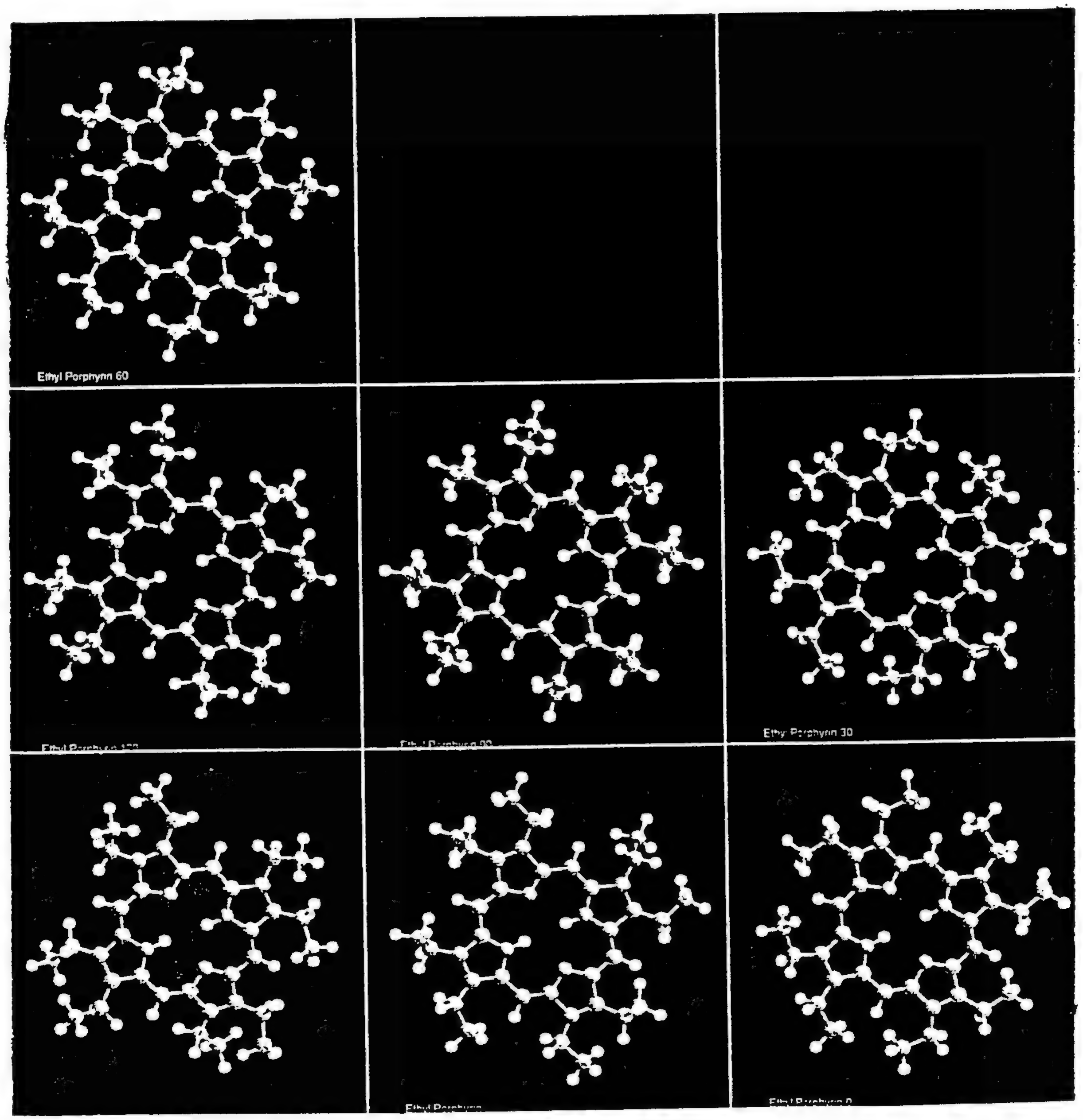
		Charges		Bond Orders	Bond Length		Bond Angle		Dihedral Angle
S	1	2.6969	0		0.000000	0	0.000	0	-
O	2	-0.9940	1	1.447760	1.458666	0	0.000	0	-
O	3	-0.9935	1	1.446640	1.437950	2	113.157	0	-
O	4	-0.9932	1	1.135374	1.456928	2	11.233	3	(127.31)
C	5	0.5590	1	0.377901	1.760195	2	106.427	3	118.38
C	6	0.0500	5	1.136516	1.446802	1	120.219	2	174.60
C	7	-0.1383	6	1.137989	1.409595	5	119.038	1	(172.07)
C	8	0.2257	7	1.103667	1.454718	6	120.940	5	(4.41)
N	9	-0.3032	8	1.383383	1.356620	7	121.892	6	(179.61)
C	10	-0.0586	8	1.138414	1.418893	9	121.375	7	176.95
N	11	-0.1173	10	1.152238	1.403211	8	114.980	9	0.25
N	12	-0.0035	11	1.683324	1.264374	10	115.142	8	179.69
C	13	-0.0392	12	1.100517	1.429947	11	113.814	10	178.41
C	14	-0.1031	13	1.312481	1.366965	12	126.130	11	(10.59)
C	15	-0.1168	14	1.486765	1.385108	13	120.835	12	175.97
C	16	0.0021	15	1.313046	1.414418	14	120.350	13	0.49
C	17	0.0024	16	1.043287	1.502273	15	119.974	14	178.68
C	18	-0.1168	17	1.313179	1.414418	16	119.974	15	(180.00)
C	19	-0.1029	18	1.486909	1.385108	17	120.350	16	178.68
C	20	-0.0396	19	1.312386	1.366965	18	120.835	17	0.49

N	21	-0.0032	20	1.006740	1.429947	19	126.130	18	175.97
N	22	-0.1177	21	1.683033	1.264374	20	113.814	19	(10.59)
C	23	-0.0578	22	1.152556	1.403211	21	115.142	20	178.41
C	24	0.2256	23	1.137523	1.419282	22	114.948	21	(179.71)
N	25	-0.3024	24	1.385109	1.355742	23	121.411	22	(0.21)
C	26	-0.1385	24	1.103047	1.455229	25	121.918	23	177.02
C	27	0.0497	26	1.318020	1.409595	24	120.968	25	179.58
C	28	-0.5582	27	1.135108	1.447744	26	119.026	24	4.40
S	29	2.6966	28	0.377815	1.759965	27	120.176	26	172.08
O	30	-0.9938	29	1.144893	1.458715	28	106.373	27	(174.64)
O	31	-0.9933	29	1.144789	1.437950	30	113.139	28	118.36
O	32	-0.9931	29	1.135281	1.457126	30	111.273	33	127.37
C	33	-0.0506	23	1.272304	1.400818	22	123.487	24	(178.86)
C	34	-0.0472	27	1.273353	1.423811	26	117.945	28	177.85
C	35	-0.0891	34	1.492695	1.371623	27	120.677	28	(0.24)
C	36	-0.1073	35	1.310968	1.405849	34	121.008	27	(2.01)
C	37	-0.1040	26	1.515831	1.421573	24	119.261	27	(179.65)
C	38	-0.0591	20	1.468822	1.395149	21	114.598	19	(178.47)
C	39	-0.1260	17	1.354302	1.376279	16	122.130	18	(179.85)
C	40	-0.1260	16	1.354439	1.376279	15	117.896	17	(179.86)
C	41	-0.0592	13	1.302012	1.394846	12	114.649	14	178.45
C	42	-0.0503	5	1.523929	1.357622	1	119.896	6	(175.82)
C	43	-0.1042	7	1.263535	1.421573	6	119.769	8	(179.63)
C	44	-0.1071	43	1.468412	1.360100	7	120.999	6	1.29
C	45	-0.0896	44	1.310438	1.405442	43	119.525	7	0.99
C	46	-0.0471	6	1.271846	1.424574	5	123.005	7	177.75
H	47	0.2694	9	0.871632	1.090000	8	109.470	7	3.05
H	48	0.3139	9	0.850818	1.090000	8	125.273	47	(179.95)
H	49	0.2696	25	0.871520	1.090000	24	109.470	23	(180.00)
H	50	0.3141	25	0.850710	1.090000	24	125.281	49	179.93
H	51	0.2112	33	0.920382	1.090000	23	119.034	28	(179.95)
H	52	0.1146	37	0.942385	1.090000	26	119.499	27	179.98
H	53	0.1482	36	0.946007	1.090000	35	120.232	37	(180.00)
H	54	0.1572	35	0.944084	1.090000	34	119.471	36	180.00
H	55	0.2034	34	0.925559	1.090000	27	119.640	35	(179.99)
H	56	0.1463	39	0.943531	1.090000	17	119.298	38	(179.93)
H	57	0.1714	38	0.939841	1.090000	20	119.884	39	179.92
H	58	0.1447	19	0.946349	1.090000	18	119.602	20	179.79
H	59	0.1468	18	0.943652	1.090000	17	119.831	19	179.97
H	60	0.1715	41	0.939855	1.090000	13	119.874	40	179.98
H	61	0.1465	40	0.943488	1.090000	16	119.329	41	179.99
H	62	0.1468	15	0.943672	1.090000	14	119.819	16	179.96
H	63	0.1448	14	0.946347	1.090000	13	119.596	15	(179.97)
H	64	0.2110	42	0.920403	1.090000	5	119.021	10	(179.94)
H	65	0.2033	46	0.925618	1.090000	6	119.640	45	(179.97)
H	66	0.1571	45	0.944114	1.090000	44	119.492	46	180.00
H	67	0.1481	44	0.946037	1.090000	43	120.227	45	179.95
H	68	0.1146	43	0.942400	1.090000	7	119.512	44	179.99

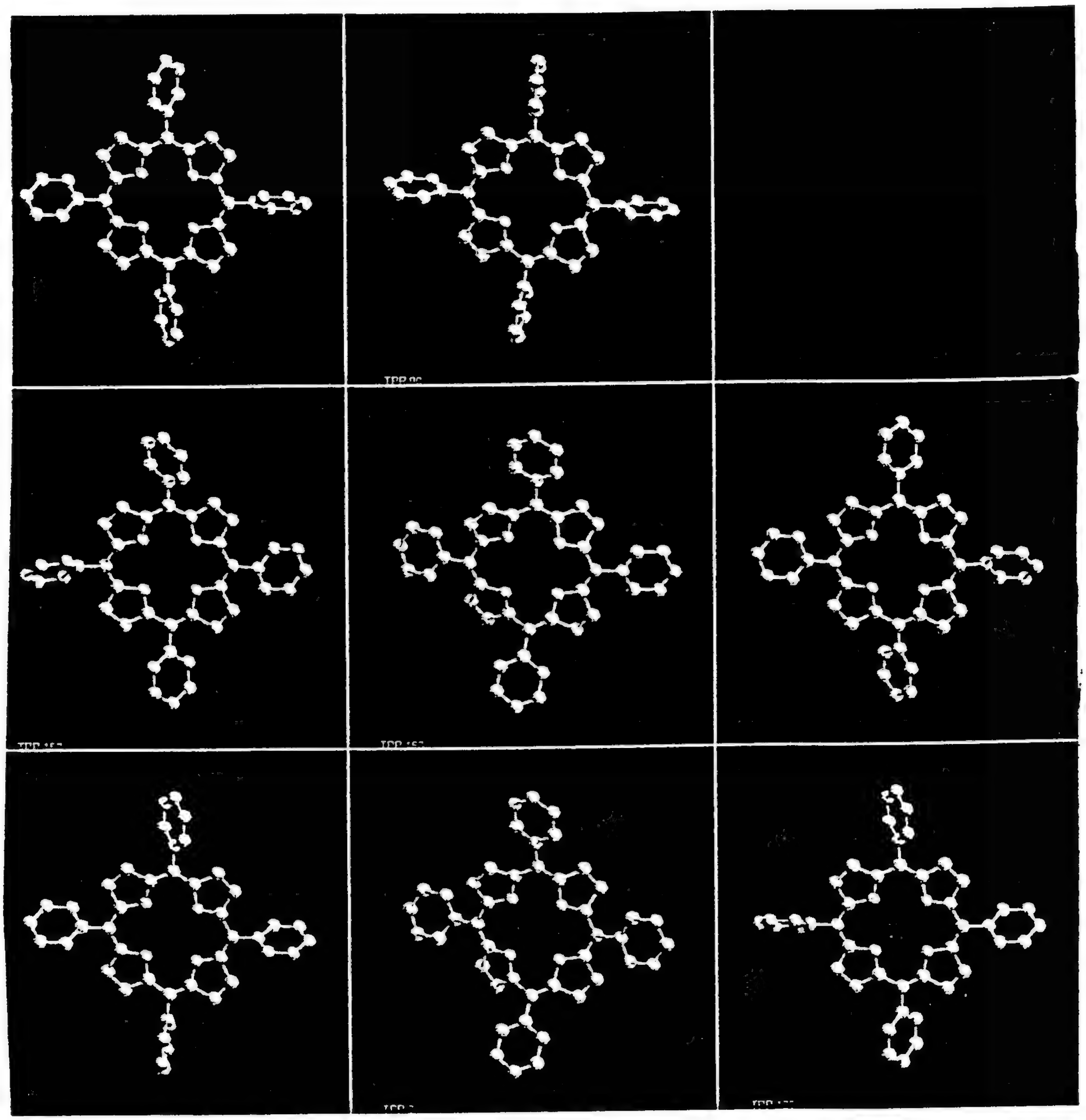
The Four different Porphyrins



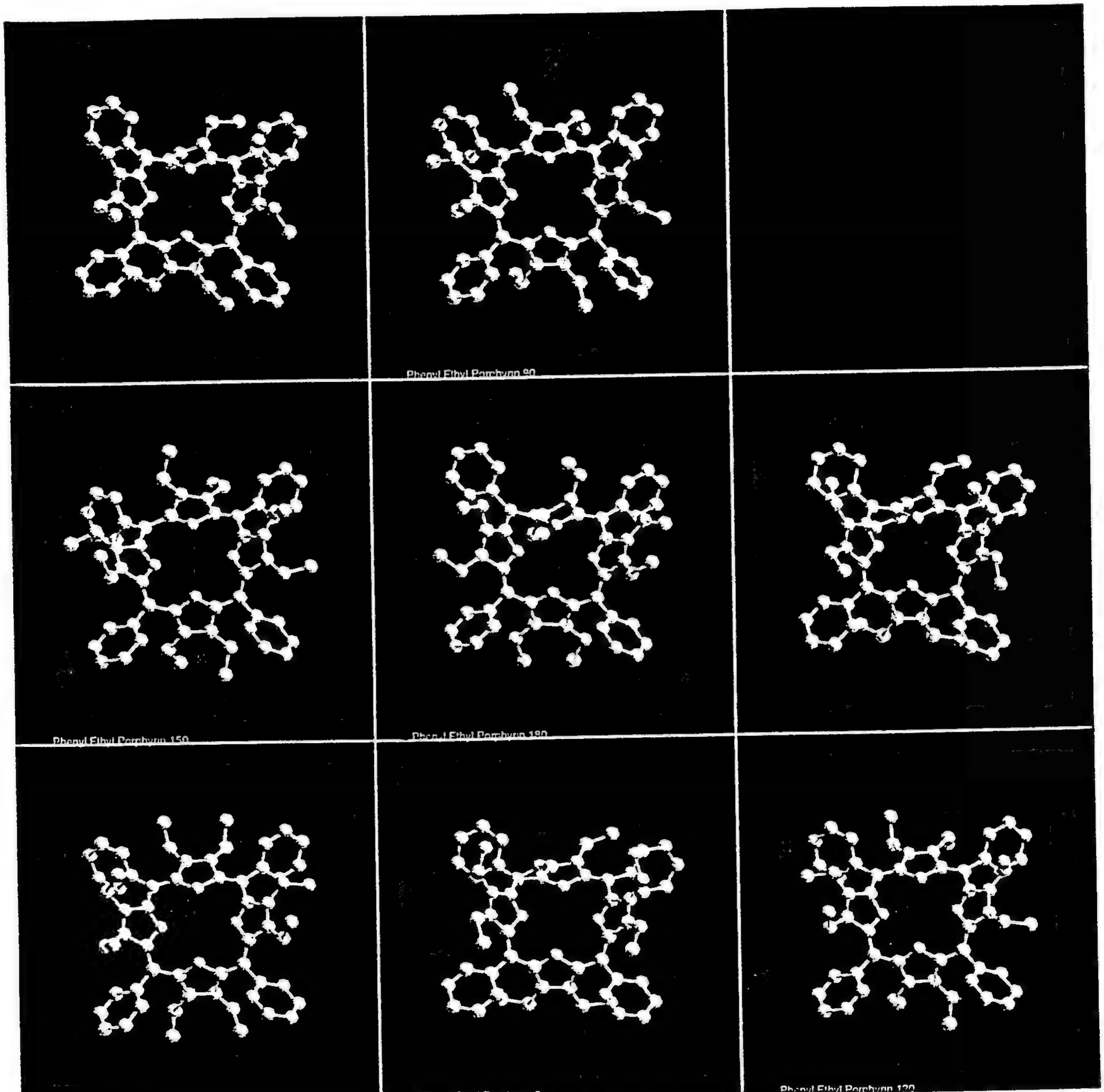
Ethyl Porphyrin



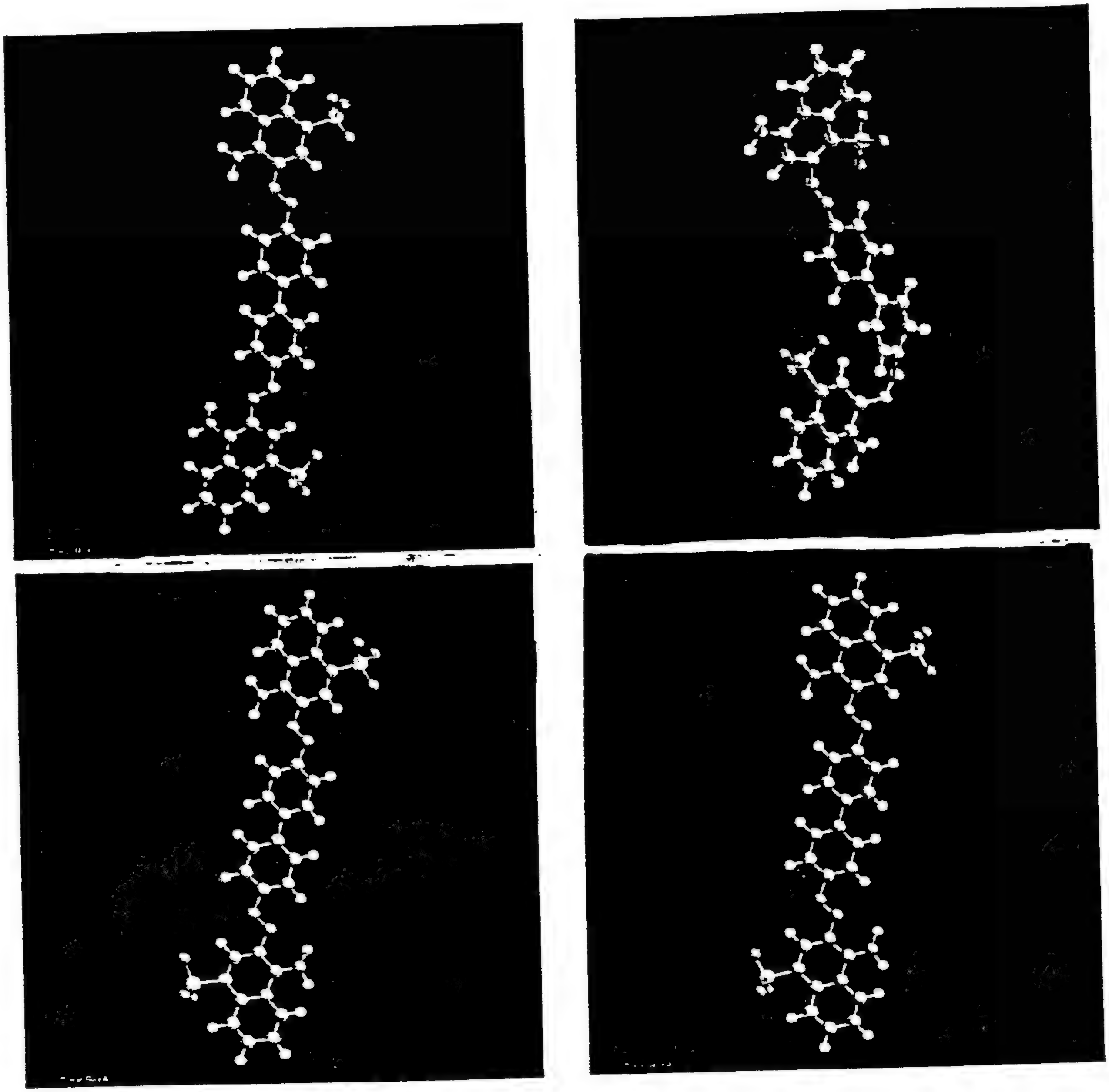
Tetra Phenyl Porphyrin



Phenyl Ethyl Porphyrin



The Four Congo Red



BIOMIMETICS: EMULATING THE HUMAN VISUAL SYSTEM FOR MILITARY APPLICATIONS

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BIOMIMETICS:
EMULATING THE HUMAN VISUAL SYSTEM FOR MILITARY APPLICATIONS

Joshua B. Nelson

Abstract

The application of biomimetics (the science of mimicking biology) in signal processing was studied. This study looked to further the information available using the knowledge concerning human vision processes that has already been discovered. Using Matlab© [MAT95] the study constructed many algorithms to test different hypotheses pertaining to biomimetics. The main hypothesis in biomimetics is that models of vision systems can be emulated to our benefit in military systems. Our goal this summer was to work toward proving that a Biomimetics-based algorithm is superior to other systems. This was achieved by first working in different directions and establishing other theories concerning the human visual system and signal processing.

BIOMIMETICS:

EMULATIMG THE HUMAN VISUAL SYSTEM FOR MILITARY APPLICATIONS

Joshua B. Nelson

Introduction

The study of biomimetics is a very diverse field containing many different areas of study and application. At Air Force Research Laboratories, we are mainly concerned with emulating these biological systems for modern weapon systems to aid with signal processing in creating what we call "smart weapons." In short, a model of the human eye must be constructed, refined, and finally emulated in an algorithm. To achieve this, one must have a solid understanding of the how the eye functions. The eye is a very complex system. It is sometimes referred to as an integral part of the brain due to a common organic origin in embryonic development.[Brooks96] Our understanding of the eye is a limiting factor in biomimetical research, but that understanding is always broadening. Hopefully people will begin to realize that biomimetics is a feasible means of remedying our current shortcomings in military applications and will try to develop more accurate vision models.

Methodology

The science of biomimetics is a relatively new science. By definition it means to mimic biological systems in man-made applications. In our case, we seek to replicate the initial stages of the human visual system in imaging seekers for autonomous weapons. By initial stages we mean the process which begins when light is absorbed by the photoreceptors and continues until the data is sent by the ganglion cells up the optic nerve. It is this process which we seek to emulate for military purposes.

The reasons for this scientific research are many. One of the main reasons is that our current seekers have shortcomings that can be overcome by emulation of a biological system. For instance, our IR seekers do not work well in an environment in which there is high moisture content or low visibility. Emulation of various biological systems may provide the means to overcome this shortcoming. There are many biological paradigms that are proven in a variety of environments such as sonar used by bats, visual system used by dragonflies, visual system used by fish, and the visual system used by humans. Because the world of nature and the environment in which military systems work are similar (i.e. time, space, color), and these systems work in the world of nature, they

should also work for military purposes if emulated. Another reason for researching biomimetics is that all of our current seekers are processor limited due to the large number of computations which they must perform. This basically means that the seekers are limited in what they can accomplish because they cannot process the data fast enough. Biomimetical systems will cut down on computational time and increase the potential of the seekers. To mimic the human visual system, one must have background knowledge of its components and their functions. The following is a brief overview of the human visual system.

The human visual system is passive which means that it does not transmit signals to be bounced off objects and then return to the eye, but instead it absorbs light signals from all objects that emit light. Objects that do not omit light are viewed as the color black by our visual system. The absorbed light passes through the cornea, iris, and lens which causes it to be refracted toward the very back of the eye. The light signal passes through the vitrous humor, a fluid that maintains pressure in the eye, and strikes the back of the eye, more commonly called the retina. Located on the back of the retina are the photoreceptors that absorb the light and begin the visual process. Fundamentally, there are two types of photoreceptors: *rods* and *cones*. The cones are also broken up into *short wavelength cones, medium wavelength cones*, and *long wavelength* cones. These are commonly called *S-Cones, M-Cones*, and *L-Cones*. The highest concentration of M- and L-Cones is at the center of the retina, also called the *fovea*. As you move away from the fovea there are more rods than cones. In each human retina, there are approximately 100 million rods compared to 5 million cones. There are also 14 times as many M and L Cones as there are S-Cones. Figure 1 shows is an example of the distribution of the photoreceptors over the retina.

Representative primate cell types and sizes with variations in eccentricity

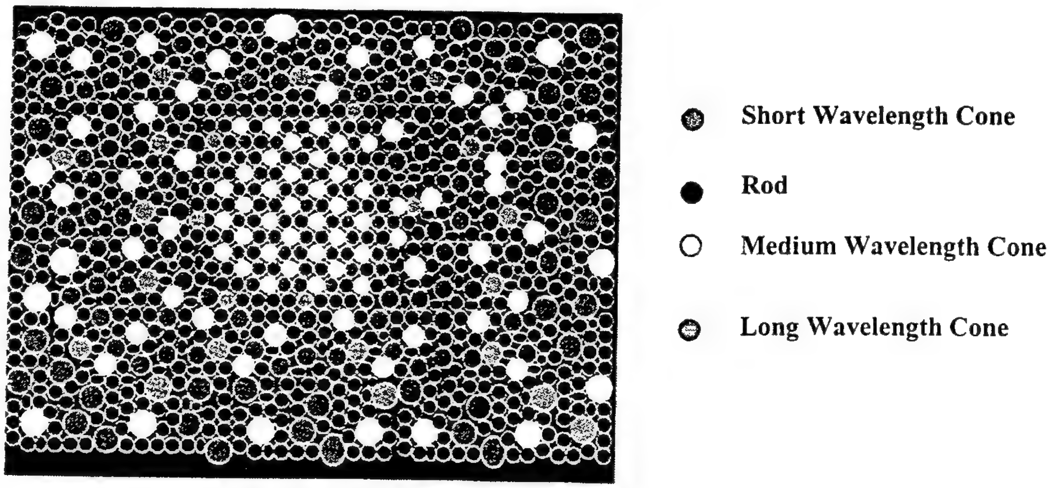

Figure 1

The rods are used to initiate vision at the *scotopic* (low light levels) while the cones are used to initiate vision at the *photopic* (higher) light level. Levels of illumination at which both cones and rods are used to initiate vision are called *mesopic*. When the light is absorbed by the photoreceptor, it is actually an *intensity* value. As the intensity passes through the photoreceptors it is transformed into an electrical current. This current is passed down to the end of the photoreceptor where the *triad synapse* is located. There is not much known about the triad synapse, but scientist believe that either a ratio or difference exist at the triad synapse between the data absorbed by one photoreceptor and it's neighboring photoreceptors. After the data is passed through the photoreceptors, it is transferred to the *horizontal cells*. The horizontal cells act as spatial filters, or position filters. They measure the position of the object emitting the signal relative to the human. The *bipolar* cells take the data and act as time filters as well as spatial filters. The horizontal and bipolar cells help to give the three dimensional aspect to an object. The bipolar cells send the data to the *ganglion* cells which in turn take the electrical current and send it up the optic nerve to the

brain. Connecting the ganglion cells together are the *amicrine* cells. The amacrine cells are responsible for determining motion. There are usually several of these cells wired to one ganglion cell. Figure 2 is a diagram of the early stages of human vision located in the retina.

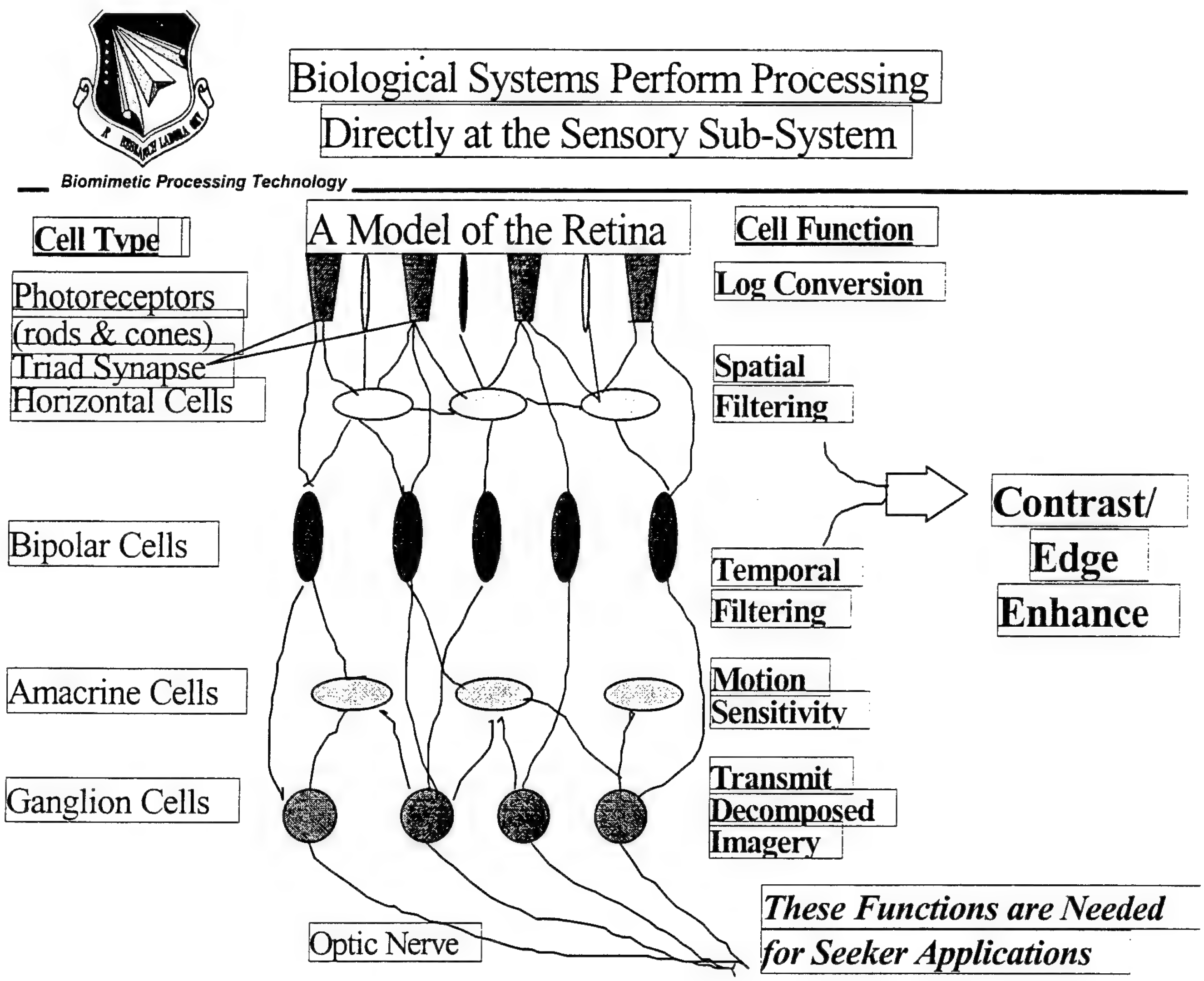

Figure 2

Russell and Karen DeValois[DEV93] published a computational model in 1992 which described the early stages of vision and explained their reasoning behind believing that a ratio exist at the triad synapse instead of a difference. This model is what we based our biological algorithm upon. Using the De Valois' ratio theory we developed what we call the *Receptor to Neighborhood Ratio* (RNR). Treating each photoreceptor as a pixel in Matlab[c] [MAT95] and each image as a matrix of light intensity values we compared each receptor (pixel) to its 8 neighbors and used this ratio to recreate the original image.

The purpose of our algorithm is to take a real world image, convert it into a simulated photoreceptor mosaic, and finally use the inverse transform of De Valois' ratio theory to recreate the original real world image. The simulated photoreceptor mosaic is just a model of what the photoreceptors actually see when they absorb the light from an object. In our algorithm, we have only modeled the fovea for the sake of simplicity. This allows us to neglect the S-Cones and rods in our algorithm. We simulated the L and M Cone curves by generating two Guassian curves. For our test image we used a contrived matrix that was 80x70 and contained 10x10 blocks of wavelength values ranging from 300 to 790 nm. An example of the contrived block is shown in figure 3.

300	310	320	330	340	350	360
370	380	390	400	410	420	430
440						
						790

Figure 3

The blocks each contain 100 pixels absorbing light at the indicated wavelength. Figure 4 is also an example of the Guassian curves which were used to simulate the absorption curves of the M and L cones.

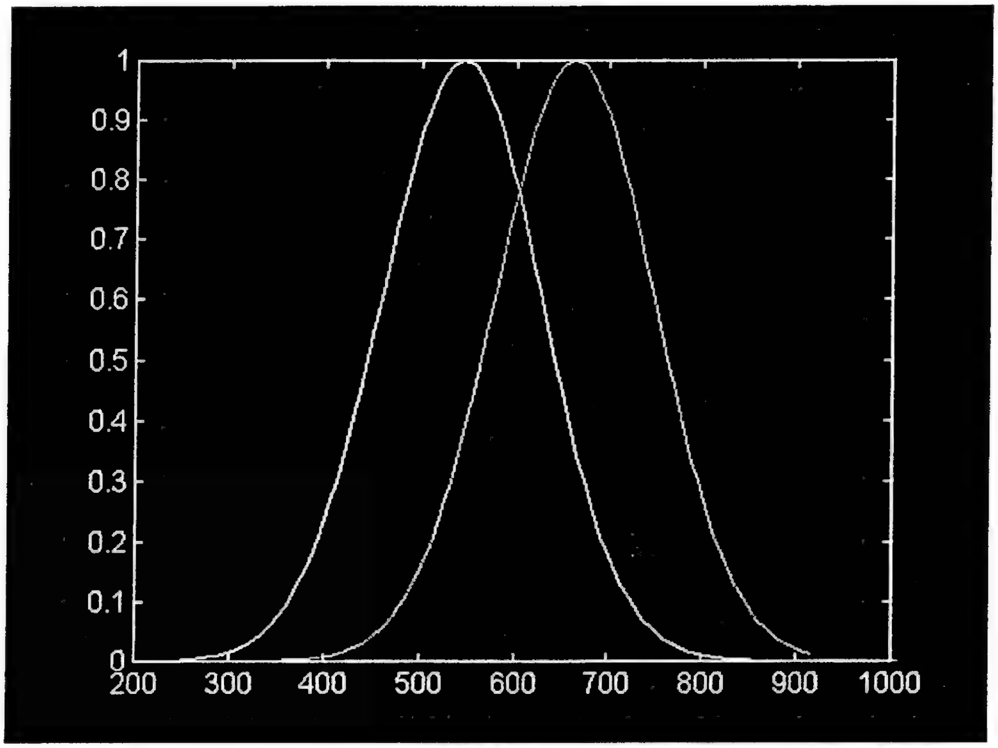

Figure 4

The method for obtaining the simulated photoreceptor mosaic uses both the real world image and the Guassian curves. The first step is to use the wavelength value of a pixel in the real world image and interpolate this value with the Gaussian curve. The result is the percent value of the absorption at that wavelength. We call this the *wavelength coefficient* (WC). Figure 5 is an example.

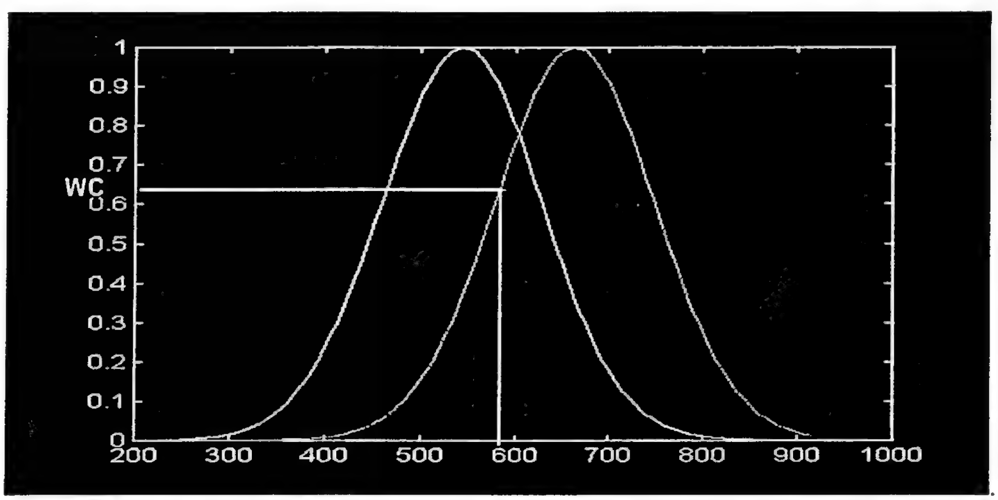

Figure 5

The wavelength coefficient is multiplied by the corresponding pixel in the intensity image of the real world image. The result is the simulated photoreceptor mosaic shown in figure 6.

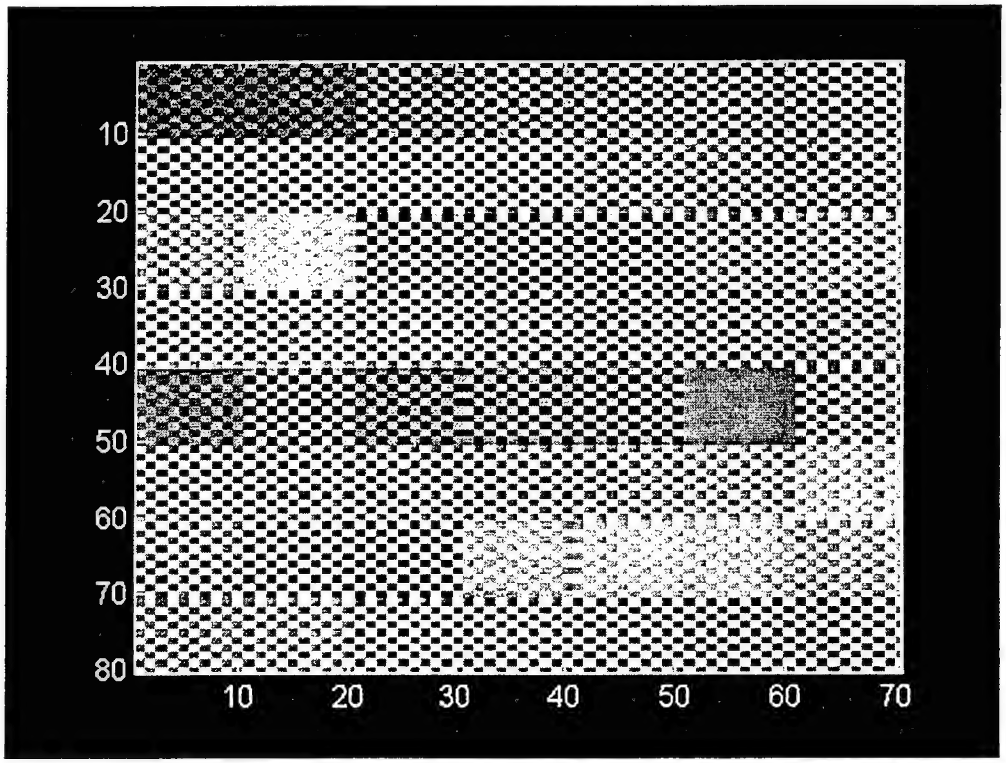

Figure 6

This is actually how the eye views a real world image at the photoreceptor level. Once the image is in this form, the goal is to recreate the original real world image. This is done using the inverse transform of the RNR, which is based on the De Valois' ratio model. Each pixel or receptor is taken and compared with its eight neighbors. If the pixel is an M-Cone receptor, then the ratio is taken by using the following formula: 6M/(4L + 2M). If the pixel is an L-Cone receptor, the ratio is taken using 6L/(4M + 2L). The ratio curve is then used to interpolate back to the real world image. The ratio curve is shown in figure 7.

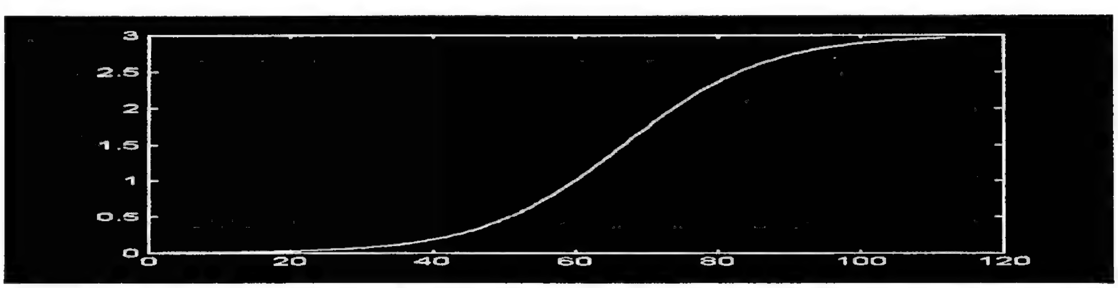

Figure 7

Interpolating the ratio along the ratio curve results is the original wavelength value being obtained. Constructing these wavelength values into an image results in the original image being obtained. However, the image is not perfectly reconstructed because of edge effects. Edge effects occur whenever a pixel is being compared with pixels absorbing light from an object with intensity that varies greatly. This is seen in the final image that is produced in figure 8.

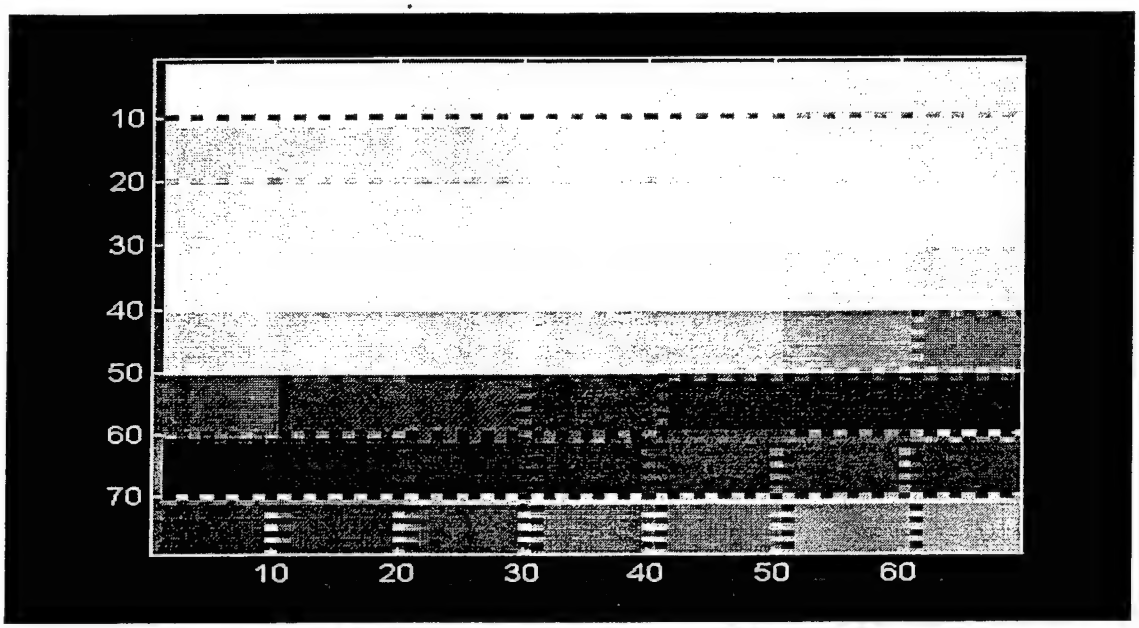

Figure 8

The edge effect may be helpful in edge detection. Investigating this effect is the subject of ongoing research.

Results

The results of our work this summer have been proof-of-concept algorithms. We used contrived data to simplify the complex systems we are researching. Eventually the algorithm must be refined and developed to work with real world dynamic data.

Conclusions

I am confident that biomimetics will someday play an important role in military operations. Furthermore, I feel that it will also become an integral part of everyday life. As people begin to understand the importance of biomimetical research and the things that can be learned from biological systems, then we should realize the full potential of the world we live in.

Appendix A

Algorithm Source Code

```
% 10 July 1998    Josh Nelson
% This program will create a wavelength map which will be
% used in conjuction with an intensity map to recreate the
% original image.
clear
%Creating first block of ten%
%for i= 1:10
%       for j=1:70
%               W(i,j)= 300 + ((j-1)- rem((j-1),10));
%       end
%end

%Creating second block of ten%
%for i= 11:20
%       for j=1:70
%               W(i,j)= 370 + ((j-1)- rem((j-1),10));
%       end
%end

%Creating third block of ten%
%for i= 21:30
%       for j=1:70
%               W(i,j)= 440 + ((j-1)- rem((j-1),10));
```

```
%end

%end


%Creating fourth block of ten.  This is the last time I am typing this%


%for i= 31:40

%       for j=1:70

%               W(i,j)= 510 + ((j-1)- rem((j-1),10));

%       end

%end


%for i= 41:50

%       for j=1:70

%               W(i,j)= 580 + ((j-1)- rem((j-1),10));

%       end

%end


%for i= 51:60

%       for j=1:70

%               W(i,j)= 650 + ((j-1)- rem((j-1),10));

%       end

%end


%for i= 61:70

%       for j=1:70

%               W(i,j)= 720 + ((j-1)- rem((j-1),10));

%       end
```

```
%end
%for i= 71:80
%       for j=1:70
%               W(i,j)= 790 + ((j-1)- rem((j-1),10));
%       end
%end

%Creating intensity map%

I=ones(80,70);

% Jan 98, GB for CSS
% Generate 2D Gaussian filter

Var = 20;
CenterM= 50;
CenterL= 70;
for i = 1:112
   M(i) = exp(-1* ((CenterM-i)^2 / Var^2));
   L(i) = exp(-1* ((CenterL-i)^2 / Var^2));
 end;

RatioM = 6*M./(4*L+2*M);
RatioL = 6*L./(4*M+2*L);
%Ratio = M ./ L;

lambda = 250:6:916;
```

```
%define detector arrangment%
%K = 0;
%for i = 1:80
%       for j=1:70
%               K=K+1;
%               if (rem(K,2)==0); D(i,j)='L';
%               else D(i,j)= 'M'; end
%       end
%       K=K+1;
%end
%save commonv W D
load commonv
%create detector image%


%noise =randn(size(I));
%I = (noise/100) + I;
%W = (noise) + W;
for i = 1:80
        for j=1:70
                if (D(i,j)=='L') r = interp1 (lambda,L, W(i,j));end
                if (D(i,j)=='M') r = interp1 (lambda,M, W(i,j));end
                mos(i,j) = I(i,j)*r;
        end
end
```

```
filter_nh = [ .5 1 .5;
              1 0 1;
             .5 1 .5;]
NHood = conv2(mos, filter_nh);
[r, c] = size(NHood);
NHood = NHood(2:r-1,2:c-1);
for i=2:79
        for j=2:69
                Ratio1= 6*mos(i,j)/NHood(i,j);


if (D(i,j)=='M');
        if (Ratio1 > max(RatioM)) Ratio1= max(RatioM); end
        if (Ratio1 < min(RatioM)) Ratio1= min(RatioM): end
        estw(i,j) = interp1(RatioM,lambda,Ratio1); end
if (D(i,j)=='L');
        if (Ratio1 < min(RatioL)) Ratio1= min(RatioL); end
        if (Ratio1 > max(RatioL)) Ratio1 = max(RatioL): end
         estw(i,j) = interp1(RatioL,lambda,Ratio1); end
end; end;
%for i = 1:80
%       for j=1:69
%               if (D(i,j)=='M'); Ratio1= mos(i,j)/mos(i.j+1);end
%               if (D(i,j)=='L'); Ratio1= mos(i,j+1)/mos(i,j);end
%if (Ratio1 > max(Ratio)) Ratio1= max(Ratio); end
%if (Ratio1 < min(Ratio)) Ratio1= min(Ratio); end
%estw(i,j)= interp1(Ratio,lambda,Ratio1);
%       end
```

```
%end

mse = zeros(size(W));
r=2; k=1;
        for i = 1:8
                c=2;
                for j =1:7
                        mse(r:r+7,c:c+7)= (W(r:r+7,c:c+7)-estw(r:r+7,c:c+7)).^2;
                mseb(k)=sum(sum(mse(r:r+7,c:c+7)));
                c = c+10; k=k+1;
                end
        r= r +10;
        end
```

References

[BROOKS96] Brooks, Geoffrey, Modeling Retinal Processing Using Wavelet Theory, PhD thesis, Florida State University, August 96.

[MAT95] MATLAB©, for MATrix LABoratory, is a computational prodyct of *The Mathworks, Inc.*, 21 Elliot St., S. Natick, MA 01760.

[DEV93] De Valois, R. L., & De Valois , K. K., "On 'A three-stage color model' ", *Vision Research*, Vol. 33, No. 8, pp. 1053-1065, 1993.

BUILDING A BUILDING DATABASE

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Final Report for:
High School Apprenticeship Program
AFRL/Wright Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

And

Wright Laboratory

August 1998

Building a Building Database

Eric C. Nielsen
Xenia Christian High School

Abstract

The building of a database is an important thing. To build my database, I used Microsoft Access and Microstation 95. I used Microstation to do the blue-printing (changing the layout schematics of building 620). I imported portions (sections or sectors) of the floors in building 620 and then in Access I took every room and hallway and put a mslink in them. This was to link them to the other half of the database (which was built by my boss before I came). This database was built to make it easier for people to determine where someone worked, their rank (designation), and other information about the rooms. With this database you would be able to locate anyone's office or any office and who works in it by either clicking on the room or by selecting the person from a list and then the database would bring up where they work. This database is the best way in my mind to locate rooms and the people or items in them.

Building a Building Database

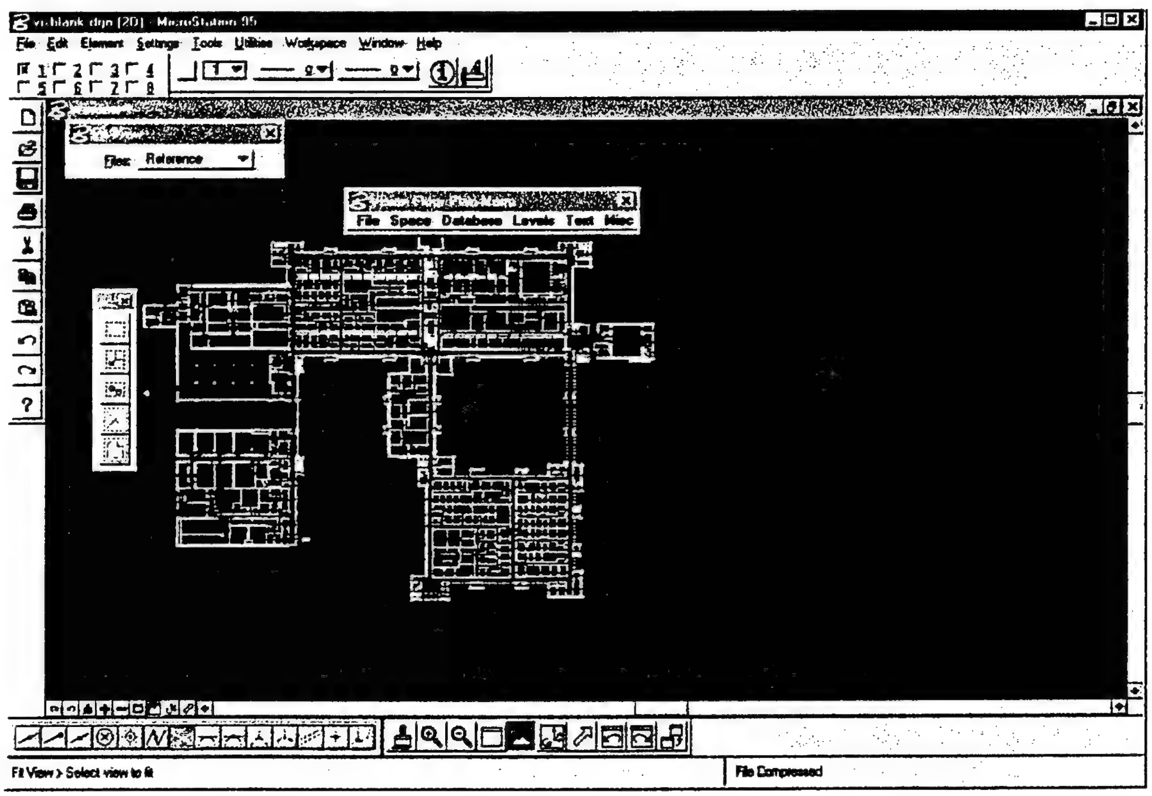
Eric C. Nielsen

Introduction

When I came to work on base, I found a huge task awaiting me or so I thought. I found out soon that this task was large but instead of too complex it was just a redundant task. I was to create a database for building 620. This database was supposed to be for easy location of people and items in the building by defining the mslink for each room. I made the database by much trial and error.

Discussion of Problem

The task that I was given to do this summer was: the building of a database. I had all the correct tools but I did not have the knowledge of how to use the tools properly. I learned the tools through trial and error. One of my errors was rather bad. I lost an entire file and had to redo it. I was not too happy about this but I started over and continued on doing the database.

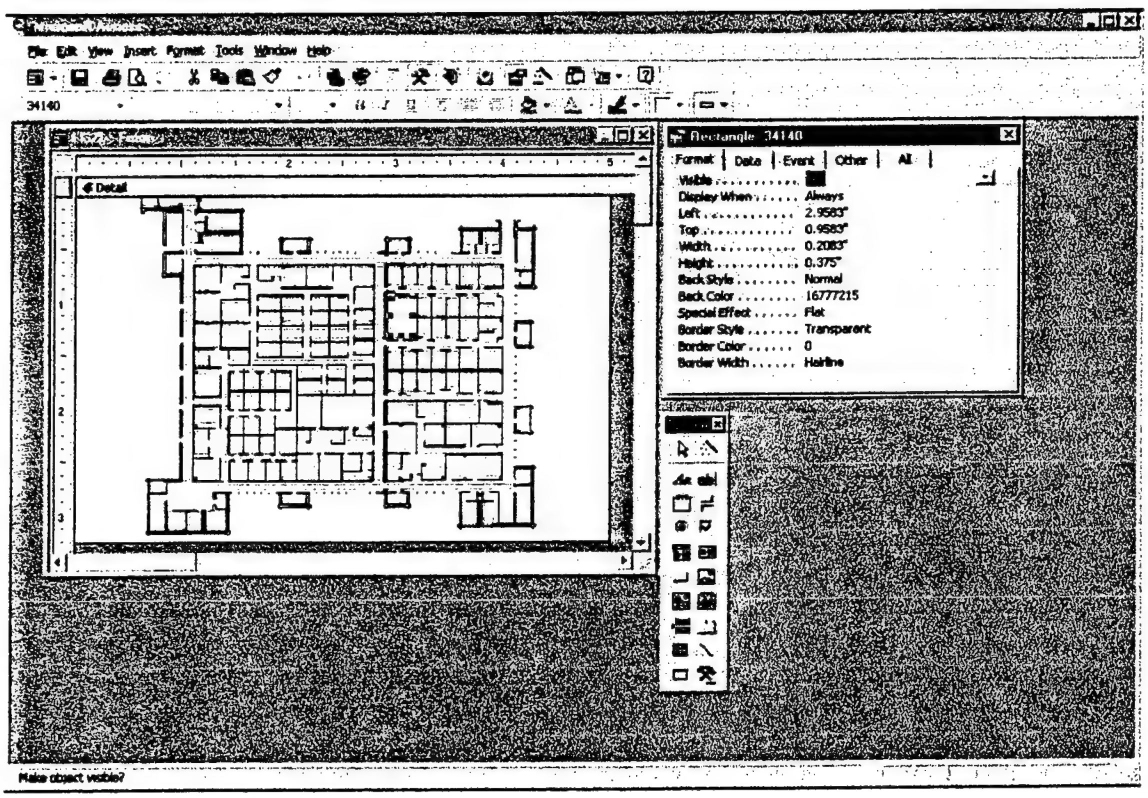


Microstation 95 on the Vision Server with a blueprint of all of floor two.

Methodology

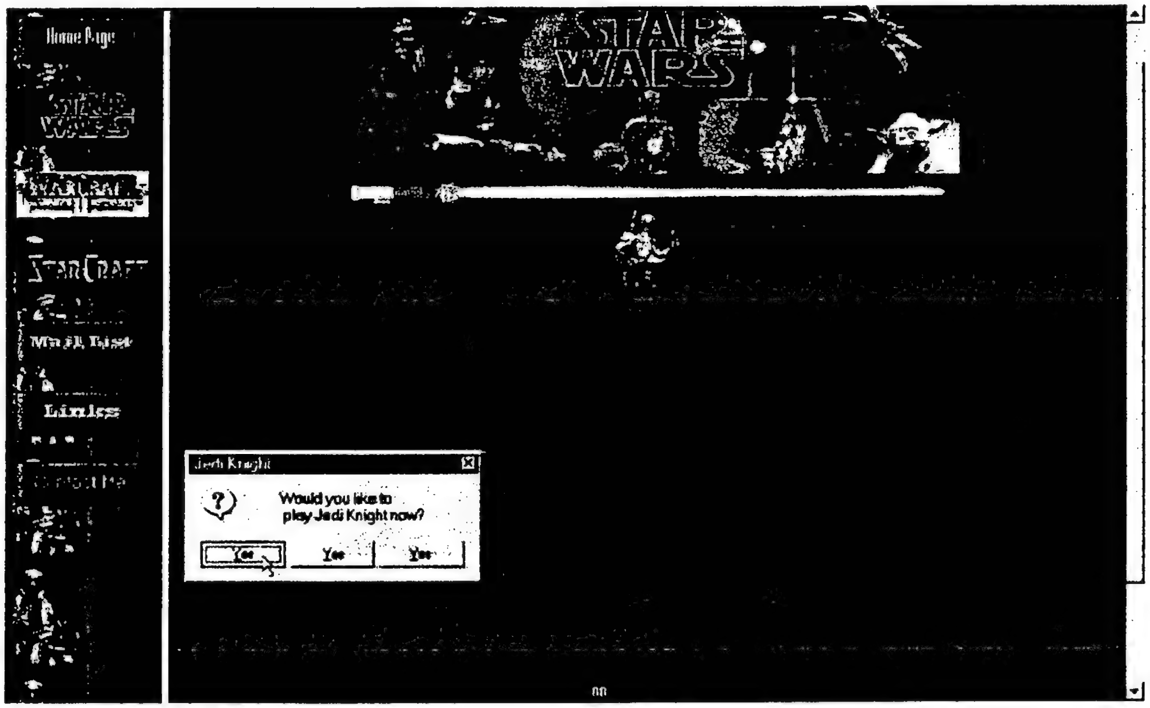
The way I made this database was with a couple different programs. I used Microsoft access and this

program was truly the best for the job. It simplified so many things. The second program I used was Microstation 95 (a program with blueprints for the building in it). I started first by playing around with Microstation and trying the different features. I took and made various simple sketches with it and learned how to use it effectively for the task at hand. I took the blueprints on Vision (the Civil Engineering server that held the blueprints) and exported them to Microstation where I could work on them. I then took the blueprints and added changes that had been made. I took and put the changes in and made them in red. I had another person check the changes for errors and I changed any errors that had been made. I took these updated blueprints and made them black and exported the blueprints as .cfg's (a type of picture file for Access). I went into Access next and imported the .cfg's as pictures and then began my half of the database. I took the image and shrunk it to a much smaller size than the original. I took the background next and made it white. I also had to take each box and make it so the were transparent and also so it was possible to click on them. I took each room, hallway, and any other place in the building and began making boxes that fit in the rooms and hallways. These boxes were numbered with a mslink (a special number one different number for every room).



Microsoft Access and one of the sections in the Database with a mslink.

Another thing that I did was: learning Html and Java in my free time, during lunch or whenever I did not have something to do. This advance in my Html and Java script skills (knowledge) has taught me a lot and next year I would enjoy doing some Html or Java scripting. I learned about creating sidebars, passwords, and how to make a web page user friendly no matter what web browser someone was using.



A Snapshot of my new web page, this is an example of what I have learned.

Results

This database has resulted in a working example of the usefulness of a database. Although, I had to make a couple hundred boxes (which would be used to click on a select a room in Access) and write numbers (actually mslink) repeatedly the end product is something that is useful and something that I can be proud of. On top of learning how to make a database I learned some Html and Java script with the help of another summer hire. I have learned how to use some useful programs and languages. These programs and languages may be useful in later life.

Conclusion

I think that this experience on base has been most worth while. I learned many things and enjoyed my time working for the base. I think that this program is great and it is a good learning experience. I would like to come back next year if It is possible.

References

Microstation 95

Microsoft Access 97

Internet Explorer 3.0

Netscape 4.0

UPDATING THE INVENTORY AND CREATING HETEROGENEOUS SYSTEM

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Final Report for:
High School Apprentice Program
Armstrong Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Armstrong Laboratory

August 1998

UPDATING THE INVENTORY AND CREATING HETEROGENEOUS SYSTEM

Bruce Wester Nolte, Jr.
A.C. Mosley High School

Abstract

As a student in the High School Apprentice Program I found it to be a great learning experience. During the summer I took a physical inventory of all the in-house chemicals in all six of the different labs. I was then responsible for updating the inventory in the Microsoft Access database. I also helped create a heterogeneous system of sand, so that DNAPL's can be studied closer.

UPDATING THE INVENTORY AND CREATING HETEROGENEOUS SYSTEM

This summer's experience of working as a High School Apprentice Student at the Armstrong Laboratory at Tyndall Air Force Base has been an educational one. I was assigned two tasks to complete during the eight weeks that I was working here. Between these two tasks I learned the importance of the inventory of the chemicals and I had the opportunity to work in the lab. While I was in the laboratory, I learned the importance of all the safety equipment in the laboratory. The first task that I was assigned was to update the Microsoft Access database for all of the in-house chemicals in all of the six different laboratories. I first printed out the entire current inventory that they had in the database and then went to each laboratory and checked off each chemical in the laboratory. I checked the manufacture, laboratory name, storage location in the lab, quantity, amount per unit, and CAS number for each chemical. For the chemicals that were not in the inventory I wrote them down, then I put them in the database with a query that I had made. For the chemicals that where on the print out I checked them off and double checked everything. I then went back to the Access database and changed the quantity for each chemical in the database. Now that I did the inventory update, anybody can search for a chemical in the database and find out how much that we have and where it is located in the lab. The second task that I did was creating a heterogeneous system of sand. We used three different types of silica sand in our experiment: fine, medium, and course. We filled a steel aquarium, with the front being a thick glass and the back having holes drilled and threaded for sample ports. We used two different patterns of ten blocks with each bloc being 50cm x 20cm x 10cm. Every second and third block we cut in half to be two blocks of 25cm x 20cm x 10cm. As we filled the aquarium we also inserted sample ports in the rear through pre-drilled holes. As we were filling the tank we encountered a few problems with the tank and our method of filling the tank. The tank walls started to come in on us, so the top of the tank is just a little bit smaller than the bottom of the tank. Also, as we were filling the tank and leveling out the block that we just did, we noticed that the panels was slipping just a little. In order to fix that we built a little box that had a lead brick on it so that we could put it in front of the panel to hold it in place.